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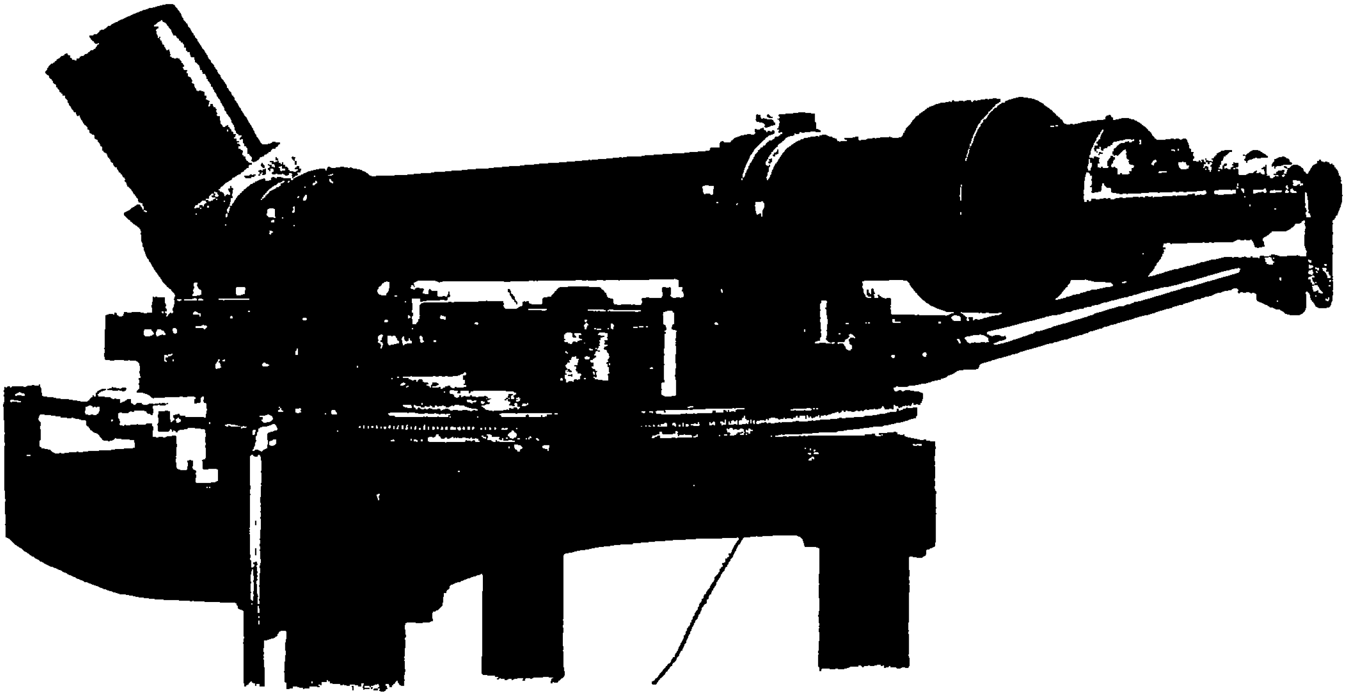


THE ALMUCANTAR.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

THE UNIVERSITY OBSERVATORY.

By Professor R. A. SAMPSON, M.A.

[Read November 1st, 1900.]

The University Observatory was built in the year 1840, three years after the incorporation of the University by Royal Charter, and its foundation at this early date speaks well for the energy with which the University began its work. The credit is to be given, I do not doubt, to the zeal of the Rev. Temple Chevallier, the first professor of mathematics. He was nominated first observer, and first in that capacity and afterwards in his modified office of professor of mathematics and astronomy, nominated the other observers and generally oversaw and directed the work that was done and the upkeep of the buildings.

From friends and public bodies the sum of about £1,440 was collected; the building was put up after the design of Mr. Salvin, and consists of a flat on the ground floor for the Observer's living, with rooms above for the instruments; all was done in a substantial, even a massive way, and neither pains nor cost seem to have been spared to make everything good of its kind. The three necessary instruments, sidereal clock, transit instrument, and equatorial were purchased, each being by the best maker of the day, and of very fair power.

After this hopeful start the Observatory settled down to regular and systematic work, on the character and purpose of which I shall have more to say hereafter, but which I may now say is common to nearly all public observatories. The library began to grow by gifts from friends and from British

and Foreign Observatories and from learned societies. Professor Chevallier left the chief part of the actual observing to an assistant, J. S. Browne, who was succeeded by Mr. Arthur Beanlands, and he by Rev. Robert Anchor Thompson, and he in 1849 by Richard Carrington, who resigned his post in 1852 after three years' active work.

Carrington's tenure of the post of Observer is the chief event in its annals. The Observatory had now been founded for some eight years, and the faults which are inseparable from a beginning had been discovered and to some extent had been corrected. What was required to ensure its effectiveness and utility was the presence of a man of ability as observer, who should choose carefully the problems to attack, who should live upon the spot, and whose first care and interest should be the efficiency of his instruments. Such a man was Carrington. his observations moreover, in particular his determination of the difference of longitude, Greenwich—Durham, bear every mark of care and capacity. He was a man of easy private means, and it was his intention to devote his life to astronomy. If he had been retained we should have had, I do not doubt, an observatory at Durham that would have ranked with the well known observatories of of the world. Not unnaturally, however, he asked for more efficiency and power than had been accorded to former observers. He desired to be independent of the direction of the professor of mathematics and to be provided with assistance; he desired more accommodation in the very narrow house; and he required the instruments to be put into a thorough state of efficiency, in view of the experience of the past eight or ten years. He liked the position of official observer to the University, and was willing to help to some degree with his own purse, to carry out these objects.

The Curators seem to have been fully aware of what a valuable man they had in Carrington; what view they took of his proposals is not recorded, but I do not doubt that they thought them too ambitious, for after a meeting with the Curators on December 16, 1851, Carrington resigned his post on the following day, evidently deeply disappointed. He

withdrew to Redhill in Surrey, where he built an observatory for himself, and pursued researches into the motions of sun spots which led to the discovery of the singular and most unexpected law governing the drift of different latitudes upon the sun's surface This discovery has set Carrington's name as one of the fixed stars in the firmament of astronomy, and it might just as well have been made at Durham, and with the instruments we then possessed

With the departure of Carrington the public history of the Observatory almost ceases Even the minutes of the Curators cease to be written up. A great chance had come, they had been unable to seize it, and now no interest was felt in the humbler routine of the past Yet among the names that follow there are some of the observers that deserve notice. Albert Marth held the post for eight years, resigning in 1863, and though he has not left much record of work done here, we are glad to think that our list includes so honoured and able an astronomer. Mr. Gleadowe Marshall, a present member of Senate, was for a short time observer, and John J Plummer has left many records in MSS and calculations of patient and careful work. Professor Chevallier died in 1872 With him the professorship of astronomy was allowed to lapse His successors were not bound by the same duties towards the Observatory, and its reaction upon University education being, as Carrington said, "probably insensible," little seems to have been done by the Senate beyond keeping the Observatory alive.

But there were many, both old alumni and other friends, who were far from satisfied that the University should keep inactive an institution, which was capable with little cost of doing creditable work, and whose claims, as a place of research, come surely only second in a University to the claims of education. Most active among these friends was Sir Gainsford Bruce, who, in season and sometimes out of it, urged upon Durham men that it was desirable to make the Observatory efficient. In particular, at a meeting of the Durham University Association, held on December 12th, 1888, a paper by him was read, sketching the state in the past

and urging with great force that it was time to move. In this he was well supported by the meeting, and in consequence of it the Senate overhauled the existing instruments in 1891, and replaced the old equatorial by a new one. However the great cost of a new transit circle prevented them renewing that telescope also, and from my own point of view, I say happily so For when I succeeded Dr Pearce in 1896 and came to consider the circumstances of the Observatory and to consult with astronomers as to the work that could be done nowadays with a new transit circle erected as usual in the meridian, I found there was a much better thing to do in setting up a transit instrument of an altogether different character, invented only fifteen years ago, and capable of experiment and development to a very great degree. The interest and scientific importance of such a work is very much greater than that connected with the transit circle where every conceivable point has been the object of the minutest study at every large fixed observatory for the past 50 years. I found many friends ready to support such a scheme by subscriptions, and in short I collected a sum which has paid for my new telescope—the Almucantar—a new clock, and a chronograph to work with it, but leaves me, I am sorry to say, in debt on account of the additional buildings that were necessary.

Let me now return and attempt to give you some idea of what we actually do at an observatory, and what our purpose is on gazing at the stars, a thing which I find almost nobody except the professed astronomer comprehends, and no wonder, for perhaps astronomy is the last of subjects to be readily grasped; with its fathomless age, its strange names drawn from the languages of nations long extinct scientifically; its endless calculations and refinements; there is a mystery hanging even over its clocks, which keep an outlandish time of their own, and all this in connection with matters as familiar and well known as the time of day, the sun, the moon, and the calendar, suggests an unintelligibility, an unimagined difficulty, which a plain man may very well think best left alone.

I will not profess to teach you the art of astronomy in the few minutes that remain; but a few sentences may not be out of place. I will dismiss very shortly one great and increasing class of observations, with which we shall have little to do. This is the class in which your telescope is free to move in every direction, and you fix it upon an object, as the moon, or a group of stars, or the spectrum of a star, or what not, for minutes or hours together, and watch or measure them by eye, or photograph them. There is in this an endless field of interest, whether for the amateur or the professed observer, but I shall pass it over, because that is not the work for which the Almucantar is designed.

The work which can be done by an Almucantar or transit circle is work which is rarely or never done outside the public observatories. The sameness and the amount of calculation it involves does not as a rule attract the amateur This is that fundamental work of recording the places of stars. We fix our telescope with just enough motion allowed to take every star at some hour or another of the night, and fixing fiducial lines in the field of view across which it is to pass, we take the time and, in the case of the transit circle, the elevation at which the star comes by, and from that deduce its position upon the sky relative to fixed points

Now the stars are the same stars that have been observed since Ptolemy and Hipparchus gave their places, in very much the same co-ordinates as we give them now, and it might be thought that at any rate from the beginning of exact observation, say with Bradley, 150 years ago, they have been observed sufficiently and their places are now known for good and all. But that is not the case. The interest of the problem is that they are *not* fixed. They have not only minute motions of their own, each one different from the rest, but in them are reflected the motion of the sun in space, the orbital motion of the earth, producing aberration of light and parallactic displacement, the precessional motion of its rotation, and lately as it has appeared, even a shift of the polar axis of rotation in the earth's body may be detected by careful watch—a notable example that further discussion

is far from superfluous. And the difficulty of finding any of these motions is enhanced by the fact that there is not in the sky one single visible fixed point to which to refer them. Now I trust that I need not enlarge on the interest and importance of investigation into the values of such fundamental quantities as these, and shall therefore take as admitted that any attempt to improve their determination justifies itself.

It only remains to show you in a few words why we expect the Almucantar to do rather better than the transit circle has done in the past—admirably as the best of these instruments perform

I have explained that an instrument designed for finding the places of stars is mounted with the least "degrees of freedom" that will suffice, and this necessary freedom consists of rotation about a single axis. In the transit circle the axis of rotation is designed to lie horizontally due east and west, but despairing of mechanical perfection we are content to make it lie very approximately in this direction, and then determine and allow for the small errors that remain. Now in the Almucantar we claim that the telescope turns with faultless truth about its theoretical axis of rotation, which is vertical, for it is allowed to adjust itself freely by floating The telescope is attached to a large, oblong, shallow, iron boat or tray, and this floats in a trough of mercury, with enough margin at the sides and beneath the bottom to put any capillary action out of fear; and connected with the trough only by means of brackets which have been carefully designed to forbid lateral and azimuthal motion, while permitting freely the slight rocking necessary for the floating parts to take up their own position. In turning the instrument from one star to another, oscillations are necessarily set up; but they subside very rapidly, and in practice we find they become insensible in a couple of minutes, and then the telescope is ready for the next observation.

This is not the only advantage we claim for the Almucantar; among others that result from adopting a vertical axis of rotation, are that difficulties of refraction are much

diminished and those of flexure of the telescope tube abolished; moreover the observations can be so arranged as to be more homogeneous in character than those of the transit circle, where one of the stellar co-ordinates is found from a time observation, and another from an observation of a divided circle, whereas in the Almucantar we take two time observations, one east and the other west Again in the design of the Durham instrument, the main part of the telescope tube is horizontal, so that the observer stands at his work in a normal attitude, in place of inverting himself upon the usual observing couch These as a whole form in my estimation a very substantial body of advantages, and the offsets which I have so far been able to discover are very slight, the chief of them being that the field of effective work is more restricted than that which is open to the older instrument

But all these are so far little more than estimates; but we have also for our assurance the solid ground of Mr. Chandler's experience, who with an instrument of less power and inferior design, working for a year at Harvard College Observatory, obtained results, which compare with distinct advantage with the standard existing determination of the best known stars

Note on the Comparison of Sulphoxides with Ketones.

By J. A. Smythe, B.Sc., Ph.D.

[Read November 26th, 1900.]

Benzyl sulphoxide $(C_6H_5CH_2)_2SO$ (M.P. 130°) was chosen for this study on account of its good physical properties, and the ease with which it can be prepared pure. Reduction of the sulphoxide does not lead to compounds analogous to the secondary alcohols and pinacones; alkaline reducing agents are without action on the sulphoxide, while acid reducing agents convert it into benzyl sulphide, $(C_6H_5CH_2)_2S$ M.P. 49°).

Treatment of the sulphoxide under varying conditions with phenyl hydrazine and hydroxylamine was without the desired effect, no trace of hydrazine or oxime being formed.

Condensation takes place when the sulphoxide and benzyl mercaptan (in glacial acetic acid solution) are saturated with hydrochloric acid gas. The beautifully crystalline compound formed, melting at 70°, is doubtless a Thiomercaptole and is at present under examination.

When benzyl sulphoxide in dry chloroform solution is treated with phosphorus pentachloride, a vigorous reaction takes place even at 0°; hydrochloric acid is evolved in large quantities and a substance melting at 70°-71° is formed as the chief product of the reaction. This body is dibenzyl disulphide $C_6H_5CH_2S.S.CH_2C_6H_5$ as was proved by analysis and by comparison with a sample prepared by the action of iodine on benzyl mercaptan.

The mechanism of this reaction is obscure, but it seems likely that the normal replacement of oxygen by chlorine takes place first, and that the compound thus formed breaks up thus:—

$$2(C_6H_5CH_2)_2SCl_2 = (C_6H_5CH_2)_2S_2 + 2C_6H_5CH_2Cl + Cl_2$$

the chlorine then replacing hydrogen in one or more of the compounds at hand.

As confirmatory of this view may be mentioned that benzyl chloride was found among the products of reaction; that hydrochloric acid is evolved in large quantities; and finally the observation of Marcker that bromine and phenyl sulphide yield diphenyl disulphide. The first reaction in the last case is undoubtedly addition to form $(C_6H_5)_2SBr_2$, which might be expected to show similar instability at ordinary temperatures to sulphur tetrachloride.

It is interesting in this connection to compare Otto's observation (*Ann d Chemie*, 136, 154) on the action of phosphorus pentachloride on $(C_6H_5)_2SO_2$ Otto gives the equation of the reaction –

$(C_6H_5)_2SO_2 + PCl_5 = PCl_3 + C_6H_5SO_2Cl + C_6H_5Cl$

from which it is evident that the phosphorus pentachloride acts simply as a chlorinating agent (*v. Appendix*).

To sum up, the analogy of benzyl sulphoxide to the ketones is chiefly structural; the sulphoxides being much more stable compounds than the ketones. Analogy in chemical behaviour apparently only shows itself in the first stage of the phosphorus pentachloride reaction, and in the condensation reactions with mercaptans.

Appendix. A few reactions of organic sulphur compounds, observed during the course of the above work, may be noted here.

Benzyl sulphide* and hypochlorous acid gave benzylsulphonic chloride $C_6H_5CH_2SO_2Cl$. M P. 91°-92°) and benzyl chloride. This is evidently due to preliminary oxidation; and it was proved, accordingly, that chlorine water has exactly the same affect as hypochlorous acid.

$$(C_6H_5CH_2)_2S \rightarrow \begin{matrix} C_6H_5CH_2 \\ C_6H_5CH_2 \end{matrix}{>}SO_2 + \begin{matrix} Cl \\ Cl \end{matrix} = C_6H_5CH_2SO_2Cl + C_6H_5CH_2Cl.$$

The already oxidised $(C_6H_5CH_2)_2SO$ and $(C_6H_5 \cdot CH_2)_2SO_2$ gives the same reaction still more readily when treated with chlorine water.

* A determination of the molecular weight of this compound by the depressing of the freezing point gave a value 212. Calculated for $(C_6H_5-CH_2)_2S$. the Mol. wt = 214. I am indebted to Mr. A. Merrick for this determination

NOTE ON MOLLASSIN.—A CATTLE FOOD.

By S. H COLLINS, F I C

[Read December 14th, 1900]

This Cattle Food was used by Mr. Nimmo and a sample obtained from him for me by Mr Greig. It appears that mollassin is used only in moderate quantities and should be considered as a condiment quite as much as a food.

The analysis of the actual sample obtained was:—

Water	31 36
Oil	·55
Albuminoids	1 25
Nitrogenous Extractives	5·08
*Sugar (as Glucose)	34 99
Other Carbohydrates	12 75
Woody fibre	6·01
Mineral matter	8 01
	100·00

It will be seen from the above composition that the value of this food lies principally in the sugar. This sugar could be bought in the form of treacle for about half the cost, but the flavour of the mollassin seems to be preferred by the cattle.

The value of a substance of this nature depends more on the amount of coarse fodder which it induces the cattle to eat, than on the actual value of its own constituents.

Mollassin is a refuse product of the beet sugar industry, and is much appreciated by continental farmers.

* Mostly cane sugar

Physiological Psychology.

By F. B. Jevons, M A., D.Litt.

[Read January 31st, 1901.]

Physiological Psychology is based upon the assumption or implies the belief that every thought, idea, emotion, wish, pleasure, pain, etc, of which we are conscious has its counterpart in some corresponding change in the grey matter of the brain; that to every psychical state or psychosis there is a corresponding nerve-process or neurosis. The two processes are supposed to be strictly parallel, in the same way that, in an interlinear translation, the sequence of words in the one language is exactly paralleled by the sequence of words in the other language; and so that by looking at either we can tell with certainty what is going on in the other. Hence the well-known name of the theory: psychophysical parallelism. Inspection of one series enables us— or if we had the requisite knowledge would enable us—to read off the other, even without seeing it. If the science were complete and if we had instruments which enabled us to see through a man's skull, then by observing the physiological changes which took place in his brain we could say with certainty exactly what his thoughts and feelings were. If we call the brain-process a phenomenon, then the corresponding consciousness which goes with it has the technical name of epiphenomenon.

If now we turn to the physiological phenomena, and ask what are the causes which produce the various changes that take place in the nerves and brain, the answer is plain: they are the ordinary physical causes at work in all physiological processes: the chemistry of cerebration cannot be different from the chemistry of digestion. In both, every change that takes place is a transformation of a definite amount of

energy, and the re-distribution of a definite amount of matter. In both stomach and brain, every change that takes place is inevitably determined by antecedent causes, which are themselves the outcome of previous causes themselves equally predetermined. Brain-processes and nerve-processes are part of the mechanism of the world, and are purely mechanical in their action. If we compare the series of physical changes to a moving railway train, what are we to say to the train of thought and consciousness which corresponds to the brain-process? The conscious process corresponds to the brain-process in the same way that the shadow cast by the railway train is the counterpart of the moving train. The actual phenomenon is the train, consciousness is the epiphenomenon, the shadow cast by the train and accompanying it. And the train moves the shadow, not the shadow the train The shadow does not even move itself --any motion it has is due to the movement of the train. The movement of thought is not spontaneous, nor has it even laws of its own: it is merely the concomitant of certain physical changes which are entirely regulated by mechanical laws. The concentration of the attention on this object rather than that is neither spontaneous (an exercise of free will) nor determined by the attractiveness of the object which fascinates the attention. The moving shadow owes its motion to the movement of the train, not to itself If the train stops, the shadow will stop. And if the train is cremated, there is an end of the shadow.

Physiological psychology obviously comes into conflict with the common-sense view of things. The man of common-sense believes that he is free to choose the good and eschew evil. As for his brain, which he has never seen, I suppose he regards that as the organ of thought, just as the eye is the organ of sight; and that he uses and controls both, just as he uses and moves his hands—in fact that the shadow moves the train. Even the Necessitarian or Determinist, who holds that choice is not free but determined by motives, still holds that motives are purely mental or psychical, and that one psychical state causes the next, that one idea

suggests another and so on—in fact that the shadow causes its own movement. But both notions are plainly illusions, if psychophysical parallelism be a fact. Free will and immortality of course both go by the board.

What reasons then have we for believing that it is a fact? I take it for granted that there are reasons, and that if there were none we should not be expected to believe it. But if there are reasons, then those reasons are mental phenomena, they belong to the train of thought, they are points in the psychical line, not in the physical line parallel to it. We start then by being conscious, and it is from the facts of consciousness, the points in the psychical line, that we infer the existence of the physical line. We cannot start in our reasoning from something of which we are not conscious. And if we start from the facts of consciousness, then the existence of the physical facts is an inference from them. Thus the position of things seems reversed. Physiological psychology took it for granted that the physical facts were the sole substantial reality, and the mental facts unsubstantial shadows—that the physical facts had an independent existence of their own, quite unaffected by the appearance or disappearance of their shadow. But now it looks as though consciousness were the reality, and the physical changes but the shadows which the facts of consciousness project when the light of reason falls upon them. And it also seems that if there were no consciousness there could be no reason for believing in the existence of matter. The whole and sole evidence for the existence of the physical world is the evidence of consciousness; and to treat that evidence as unsubstantial and shadowy is to discredit the existence of matter as well as of mind. The facts of consciousness are the primary facts, and all theories must bow before them.

There is therefore something to be said for the man of plain common-sense who, when told that he can be scientifically demonstrated to be merely a conscious automaton, says "So much the worse for science." There is something to be said for him; but how much? What are the reasons for believing in psychophysical parallelism?

The first is that there are certain facts established by observation and confirmed by experiment which indicate that some psychical processes are dependent on brain-processes. Generally speaking we may say that changes—whether normal or abnormal—in the brain processes are followed by corresponding changes, normal or abnormal, in consciousness A blow on the head may produce unconsciousness, the normal withdrawal of blood from the brain during sleep produces dreams. Toxic agents introduced into the blood circulation of the brain result in hallucinations and the visions of the opium eater, or in that gladdening of the heart of man which is due to wine The physical processes which are embraced under the term "indigestion" undoubtedly find their expression in the discomfort which is a fact of consciousness Indeed unless the feelings of a patient, which are indubitably psychical processes, were causally related to the physical processes of the body, there would and could be no art of medicine. Unless control of the physical processes of the body produced that relief from pain which is a psychical process, the medical art would scarcely be in request Again, though the details may not be clear, it is extremely probable that both in animals and in man, development of mental power runs parallel with the development and differentiation of the brain and nervous system. And in some cases the details are clear even now. Thus it is in animals which have developed a keen power of scent that the olfactory lobe of the brain is most highly developed.

Now are these facts sufficient to prove that the physical and psychical processes are parallel and may as such be in Euclid's words "produced ever so far both ways?" The reply given to this question by the most powerful supporter of psychophysical parallelism in modern times, Professor Münsterberg, is that all the facts established by observation and experiment are not decisive in favour of the theory.*

Now this declaration is of the highest importance because

* H. Münsterberg, *Psychology and Life*, p. 42.

it is symptomatic of a change which is coming over, or I think I may say has come over, men of science. It is a change which affects the very foundation of science and of our views of life, of man and of his relations to the universe. Why is it that the observed facts are not sufficient to prove the theory of psychophysical parallelism, and are incapable of providing a rational justification for the conviction, which nevertheless is strongly held, that the theory is true? It is that though there are some facts in its favour, though it has proved true so far as we have gone, still we have gone such a little way, the unknown facts so vastly outnumber the known facts, that at any moment we may stumble across some contradictory fact fatal to the hypothesis; at any moment the theory may break down. And the number of the known facts is so extremely small as compared with the number of facts yet to be known, that it can scarcely be considered even probable that the psychophysical parallels will prove to extend "ever so far both ways."

But if we are influenced by these sceptical considerations to give up psycophysical parallelism, we shall find ourselves logically compelled to give up the truth of science generally. If the only basis of science is observed facts, then we must admit that all the facts together, which science has observed in our little corner of the universe, are infinitesimally few as compared with the sum total of the whole universe, and are ridiculously inadequate for the purpose of establishing universal laws, and making general statements about what always happens everywhere. Really, the notion that man's petty powers of observation enable him to state authoritatively what does and does not happen all through the universe belongs to what has been called the "geocentric" stage in his mental development. As long as man believed that his earth was the centre round which the universe revolved, that it was for his special benefit that the universe was designed, and that his fate was the sole preoccupation of the Power that maintains all things, so long it was perfectly consistent of him to lay down universal laws and talk confidently about what always happens. But

surely at the present day we have larger views; man's little world has been put in its proper place; and if the day of geocentric theology is over, the time of geocentric science is also gone.

If we say that science is based on facts and facts alone, then we must admit that the facts are not sufficient to prove its truth. If we approach the foundations of science not from the geocentric point of view but with perfectly open minds we must confess that the truth of science is to the end an open question. This conclusion is indeed frankly admitted by some men of science, who declare that the theory of science is but a working hypothesis As a rule they generally also go on to say that they are prepared to abandon it if ever they find it fail to work. But they generally also say so in a tone which implies that they consider it absurd to doubt the truth of the hypothesis. Their position then is that of men who believe in something, and state their life's work on something, which they know they cannot prove to be true. If they also hold, as sometimes is the case, that science is the only truth, then their position is that the only truth is that which cannot be proved. And as their object in life is only to believe what can be proved, obviously their position is not permanently tenable. As a matter of fact this position, which is that of philosophic scepticism, has rarely been maintained in the history of thought for more than a generation. It is invariably followed by a violent reaction to the opposite extreme, viz., to philosophic dogmatism. Within the present generation, thought has travelled the whole distance from the one extreme to the other; and the completion of the movement is indicated by the form which the theory of psychophysical parallelism has taken in the hands of its latest and most distinguished exponent, Professor Münsterberg. Let us therefore return once more to our immediate subject—physiological psychology.

We have seen that there are some facts which show that in some cases psychological processes are conditioned by physiological processes, that the action of mind is determined by the mechanical laws of matter, that the physical

mechanism is the real train and that our conscious states are but the shadows cast by the train. But we have now to recognise that there are other facts pointing in exactly the opposite direction and indicating that psychical changes are the real causes preceding and producing physical effects Thus, it is an established fact in medicine that the action of the imagination produces important physiological effects: the confidence of the patient in his physician may be as valuable an agent as anything in the pharmacopœia. Fear exercises a depressing effect on the physical system. Imagination will produce not merely imaginary but actual illness, it may even lead to the production of stigmata on the body Apart from abnormal conditions, all our emotions have their physical consequences, blushing, frowning, fidgetting, etc., which we term "the expression of the emotions" Finally, in addition to these involuntary physical processes which seem to be the mechanical effects of our inward mental states, there are all our voluntary actions, which on the evidence of our own consciousness are physical effects deliberately intended and actually caused by us.

How now does the theory of psychophysical parallelism stand, in view of these facts? The theory is that brain processes (that is physical processes) and mind processes (that is psychical processes) are parallel, and therefore can never meet But in point of fact, so far from being parallel, the two kinds of processes are apparently perpetually passing into each other. So far from the physical processes being always the cause of the psychical processes, it is the psychical, purely mental processes of imagination and will which frequently control and determine the physical movements. So strong is the testimony of consciousness and common-sense on this point that there has been a marked tendency on the part of many scientific men—especially on the part of those who hold that science is but organised common-sense—to drop the theory of psychophysical parallelism, and to regard Huxley's "conscious automaton" as a piece of scientific humour, not to be taken seriously.

But the question comes whether science can afford to

drop the theory. Now many men of science hold very decidedly that it cannot, for the simple reason that to drop it is to give up the law of the conservation of energy, and so to remove the very keystone of the arch of modern science. To admit that in some cases, or in any case, psychical processes determine material processes is to admit that mind can move matter, that the shadow moves the train, that energy can be created and is every moment created. If so, then the whole of modern science comes down with a run, and the attempt to exhibit the universe as a mechanism and to explain everything by purely mechanical laws may as well be given up at once—science's occupation is gone But the motto of science must be: Thorough. Its watchword · All in all or not at all To abandon the outpost of psycho-physical parallelism, no matter how great the host of hostile facts arrayed against it, is to abandon the cause of science altogether. In a word, science is systematised knowledge; and being so, the whole system must stand or fall together If facts collide with it, so much the worse for the facts. They must be denied, explained away as illusions, got rid of in some way—or, if that is impossible, then those who persist in appealing to them must be anathematised, excommunicated and cast into that outer darkness where the unscientific gnash their teeth.

Now, this is that dogmatism which, as I have said, is in the history of thought, the reaction which inevitably follows a period of philosophic scepticism. It is dogmatic because it assumes that it is already in possession of all knowledge, because the articles of its creed are fixed and immutable, and therefore cannot tolerate those modifications and changes which are necessary if they are to adapt themselves to the progress of thought and to provide adequate expression for fresh facts and new ideas. The difference between a dogma and a working hypothesis is that, when new facts turn up, the working hypothesis can be modified to meet them, and by so modifying itself continually approximates more and more closely to the truth; whereas a dogma is something that may not, must not, be modified, and is therefore continually left

more and more behind, as knowledge moves forward. Every dogma was in the beginning a working hypothesis—one, that is to say, which might be given up, or at any rate, modified, whenever necessary. A working hypothesis becomes a dogma, when it is no longer regarded as a provisional hypothesis but is proclaimed to be an absolute truth not to be given up under any circumstances. As long as it is a working hypothesis, it is a living thing, can assimilate new facts, and grows and thrives by doing so. The dead dogma rejects facts; and it is this rejection which shows that it is dogma and dead. If we enquire why the dogma fails to explain the new facts, the reason is plain; it never really did explain the facts which it was originally supposed to account for when it was elevated to the dignity of dogma.

What then is the particular dogma in this case, which rejects facts because it cannot assimilate them, and pronounces the man who dares to question its truth—anathema, which being interpreted, is "unscientific?" It is the dictum that the amount of energy in the universe is fixed, and that, though transformations may take place, the sum total can neither be added to nor diminished. Now, there is no doubt the fact that I control and direct my own movements is in flat contradiction to this dogma. According to the theory of psychophysical parallelism every physical movement is due exclusively to some previous physical movement. According to the facts of every-day experience, some physical movements are due in part to a previous mental process, that is to say, in those cases the movement of the molecules of the grey matter of the brain is different from what it would have been, had the mental process not taken place. Now "a physical movement does not change its direction except under the influence of a physical force of a certain strength."* Therefore the mental process is followed in the physical world by an addition to the sum total of the energy existing before its action. If the volition does not increase the amount of energy, it cannot affect or change the direction of the physical movements, that is to say, I cannot move my limbs.

* Höffding, *Outlines of Psychology*, p. 56.

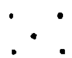
Now, though it be anathema maranatha to question the truth of the dogma, perhaps one may venture to enquire what are the reasons for believing it? For I suppose we have not yet got so far as to be in possession of "revealed science," or the verbal inspiration of scientific formulæ. In default of revelation, there are, as far as I am aware, only two attempts to prove the truth of the doctrine of the persistency of energy The first takes the form of an appeal to facts. The doctrine is then put forward avowedly as a merely working hypothesis · the doctrine is not yet a dogma It is based purely on the observation of facts: in the cases which we have observed, energy persists; in the transformations we have measured the amount on one side of the equation is always equal to the amount on the other side, therefore this is probably, and until we are better advised, universally the case But this mild conclusion is obviously insufficient for dogmatic purposes. The extent to which we have measured the energy in the universe is absurdly small, as a basis for conclusions about the whole it really affords very little presumption indeed. In fact it leaves it an entirely open question whether the sum total of energy in the universe is a fixed or a fluctuating amount. And so long as this is the case, it is also, so far as the *transformation* of energy is concerned, quite possible that the sum total is fluctuating, that is to say does receive additions, and that those additions are made by the will.

That is the conclusion to which we come if the persistence of energy is alleged to be based upon facts But that conclusion is not the one which the dogmatist desires. Indeed I think it is obvious that no argument which bases itself upon fact can be sufficient for dogmatic purposes—for this simple reason, that he who appeals to facts is at the mercy of facts, whereas the dogmatist wants something which will enable him to over-ride facts. He must therefore begin as he wants to end—that is with something higher and more cogent than mere facts. Then he will be perfectly safe. What is not based on facts cannot be shaken by facts.

Now that is exactly the position which is taken up, with

regard to the conservation of energy, by the scientific dogmatist of the present day. The doctrine is a logical necessity, not in the sense that it is an inference which you must admit if you concede the premises from which it is drawn; it is itself a necessary law of thought, the way in which the mind must think about things in space. It is not an inference from facts, but the only way in which the mind can see the facts. Obviously therefore it never can be contradicted by facts nor even come into collision with facts. We cannot undermine it by challenging the facts on which it is based, for it is not an inference from facts at all. We cannot convict it of being inconsistent with fact, because it is itself the only way in which facts can be rightly apprehended—and "rightly apprehended" means of course "apprehended in harmony with the dogma."

As far as I understand this dogmatic position, it is somewhat as follows. Take a group of dots arranged in a quincunx:—



We may distinguish the dots in the top line from the rest. That is one way of looking at the group. Or we may distinguish the centre dot from the rest. That is another way of looking at the group. Or we may distinguish the top line from the bottom and from the centre. That is another way of looking at it. But whichever way we look at it, it is the same group. There is one group, and there are three or more ways of looking at it. To say $2 + 3 = 4 + 1 = 2 + 1 + 2$, is simply to say that there are three ways of looking at the group and that each necessarily implies the other two. That $2 + 3 = 4 + 1$ is not an inference from any facts. It is a necessary law of thought. The mind cannot think otherwise. The only right apprehension of the meaning of the concept "five" consists in apprehending the facts in this way. And it is also the only possible apprehension. We are dealing with a necessity of thought.

Now what is true of the simplest arithmetical equation is equally true of the most complex equation in which the

transformation of energy can be expressed. It is a necessary truth. It is not an inference from facts, or from one set of facts to another. It is simply the same facts viewed in two ways. The facts are the same throughout. The persistence of energy is simply the necessary law of thought that A = A.

Now, the only comment I have to make on this is that it is all very good but it does not prove the conclusion, viz., that the total energy in the universe is a fixed amount. For the sake of argument, I am perfectly willing to admit that two and two make four. But that fact in itself proves nothing whatever about the amount of energy in the universe. The fact that two and two make four tells us nothing whatever about the total number of things in the universe, still less does it prove that that total never increases or decreases In the same way the physicist's equations do not enable us to draw any inferences whatever as to how much energy there actually is They simply show that any fixed amount may appear in one of several equivalent forms, not that the total amount in the universe is fixed. The fact that five dots on the blackboard may be regarded as divisible either into 3 + 2 or 4 + 1 does not enable us to tell how many dots there are on the whole blackboard It certainly tells us nothing about the laws according to which dots appear upon the board and are removed from it. Yet the scientific dogmatist in effect argues thus: the five dots on the board may be analysed in various ways, therefore no additional dot can possibly be put upon the board, nor any existing dot possibly be wiped off. Dots are persistent, uncreated, indestructible, and can neither be increased nor decreased in number. The whole of the mechanical theory of the universe is based upon the necessary law of thought, that great truth, of the indestructibility of dots.

A moment ago I was willing to allow that two and two make four, for the sake of argument. Perhaps just for the sake of argument, you will allow me to assume that dots on a blackboard are not eternal. I will then ask whether the truth of the proposition that 2 + 2 = 4 is in the least affected by the fact that the total number of dots on the board some-

times increases and sometimes decreases? If the energy in the universe is receiving constant additions, are the physicist's equations any the less true? 2 + 3, 4 + 1, 2 + 1 + 2, are simply different ways of looking at the same five dots Or on the doctrine of the persistence of dots, you may say that they are transformations, and that the same five dots persist through all the transformations But is that truth in the least impaired by admitting that the total number on the board is variable? Supposing it does vary, surely it remains equally true of any five of them, that they = 2 + 3 or 4 + 1, etc. Suppose that there are only five on the whole board and that then a sixth is put on: what would be the result? Why! that we should analyse the new group into 3 + 3 = 4 + 2, etc., and that we should find our equations absolutely undisturbed. In the same way an addition of energy, caused by volition, would result not in the equation of 3 + 2 = 6 but in the equation 3 + 3 = 4 + 2. The introduction of the new dot necessarily affects both sides of the equation, because the two sides are simply different ways in which the same dots (including the new one) present themselves.

In fine, the physicist in his experiments assumes that he is dealing with a definite amount of energy and that it is constant—that when he is talking about 5 he means 5 and not 6. Thus the doctrine of the persistence of dots amounts to this, that so long as we are engaged in analysing 5 into 3 + 2, etc., we must assume that we are dealing with the same number of dots throughout the analysis, or, if you like, that the same dots persist throughout the analysis. When tracing the transformations through which a definite amount of energy passes, we must assume that we are dealing with the same amount throughout, or if you like that the same amount persists throughout.

But according to the psychophysical parallelist, if this assumption be granted, then you cannot move your limbs, because if you did, mind would act on matter, and your volition would add to the amount of energy existing before the volition. I submit that the psychophysical parallelist

is really arguing that because 2 dots + 3 dots = 5, therefore a sixth dot can never be put on the board, therefore when we see it put on the board we are not to believe the evidence of our senses; and when we put it on ourselves we are to shake our heads and say "Ah! that is an illusion." An argument of this kind, which commands us to reject facts, because it is incapable of assimilating them, is known in philosophy as a dogmatic argument The dogmatic phase through and out of which we are passing at the present day has manifested itself in the attempt to erect abstract mechanics into a final and exhaustive theory of the universe The fallacy of this particular dogma consists, as I have already indicated, in confusing calculation with measurement. Now abstract mechanics calculates but never measures It tells us nothing about real levers, or crowbars, or the effects which they actually produce, but only what effects they would produce, if they were lines of a given length, and if they were made not of any actual metal but of some material absolutely unalterable in form or dimension In fact it never deals with concrete things, or describes what actually goes on in the real world It is a set of purely hypothetical statements of what would happen if the world were made up of mathematical constants—which it is not.

Abstract mechanics assumes, as it is fully entitled for scientific purposes to assume, an abnormally simple structure for the universe. Sometimes it stops there, and commits only the comparatively unimportant error of imagining that it has avoided the necessity of considering the actual structure at all—as being a thing which may safely be neglected. The trouble begins when *dogmatism* supervenes, when the very existence of the actual structure is denied because it differs from the simplified structure assumed for the purposes of abstract mechanics, when we are told dogmatically that certain things cannot take place because abstract mechanics cannot account for them. But though the trouble begins here it does not end here If the dogmatism which is based on an erroneous extension of the sphere of abstract mechanics simply led to a conflict between dogmatism and philosophy,

or between dogmatism and common-sense as to the existence and the freedom of the will, the man of science might leave the parties to the dispute to fight it out between themselves. But the consequences of dogmatism go much further and affect science much more nearly. They lead to the doctrine that it is necessary, dogmatically necessary, for science not merely to simplify the data of its problems—a proceeding which is indeed both permissible and necessary—but to falsify the data. Now against the doctrine that falsification of fact is essential to science, it is the business of the man of science to protest. And it is precisely the theory of psycho-physical parallelism which, through the mouth of Prof. Münsterberg, proclaims that falsification of fact is essential to science.

What then are the facts which are fatal to psycho-physical parallelism, and which must therefore be perverted and falsified if we are to believe in it? They are psychological facts—sensations, emotions, judgments, volitions, ideas, etc. And it is the business of the scientific psychologist to ascertain in what ways these facts do actually co-exist with each other, or follow one upon another—to establish uniformities of co-existence or sequence—to discover the laws by which ideas are associated with each other, or by which ideas tend to pass into actions. Now it is admitted on all hands that such psychical laws can only be discovered from the study of psychical facts; and that the corresponding physiological processes throw no light upon psychology. No one is clearer on this point than Prof. Munsterberg, who says:—"We cannot have as psychologists any interest in the question of the special brain process which accompanies a special psychical phenomenon; that is physiology, and psychology has nothing to learn from it. We take for granted that such a connection exists, indeed our whole explanatory psychology would collapse if we allowed the slightest exception, but we do not learn anything about the psychical facts themselves when we hear that the process takes place in the cortex or in the sub-cortical centres, in the ganglion cell or in the dendrite, or in the front

part or in the side part of the brain."* It seems then from these words that the psychologist gets no assistance from physiology in his attempts to ascertain the laws which govern psychical facts. We are also told that the observed facts do not warrant us in believing that there is any correspondence or parallelism between the physiological and the psychical processes The facts do not support the hypothesis of parallelism, and the parallelism, if it existed, would not help psychology one bit. And yet, though the hypothesis is not founded on fact and is absolutely useless for the science of psychology, the psychologist is bidden, under pain of excommunication, not merely to accept it but to falsify the facts of his science in order to bolster up this metaphysical dogma. The only way, we are told, by which we can save the hypothesis of psychophysical parallelism, is to assume that all psychical processes are in the last resort sensations. If we make this assumption, then we shall have on the psychical side a series of successive sensations which will exactly correspond to the series of brain changes on the physical side But in point of fact there are many psychical processes which are not sensations Thus in the process of judgment, we are aware of, say, two sensations, and we judge them, say, to be different But the judgment or declaration that they are different is not a third sensation. Yet it is a psychological process: it is something we do, and it is not a sensation So too the process of choice: we have sensations of two things and we choose between them, something certainly takes place, when we do so, and that something is not a sensation. And, generally speaking, we may say that having a sensation, being aware of something, is fundamentally different from doing something. But, the dogmatist tells us, if that is so, then the theory of psychophysical parallelism breaks down. Therefore although we undoubtedly do do things, the psychologist, in the interests of dogma, must not be allowed to admit the fact. On the contrary he must be ordered to pervert the facts and to say that we never choose or judge or will or do anything, but in all cases are

* *Psychology and Life*, p. 67.

simply aware that something happens, and that that something is a sense-perception. Thus, I have a sense-perception of white, another of black, and I judge them different. Is the judgment a third sense-perception? If it is then through what sense is it perceived? Is it a sensation of sight? Then what is its colour, its shape? Whereabouts on the blackboard is it? I see the board that it is black and the chalk-marks that they are white; but I do not see any third thing, when I judge black and white to be different. But if the judgment is not a sense-perception, then it is a falsification of fact to say that it is. And why is the psychologist commanded to falsify the facts? Because the facts are fatal to the psychophysical theory; and if the psychophysical theory breaks down, then the methods of abstract mechanics fail to afford an explanation of a large and important section of knowledge, and it will have to be admitted that the universe is not purely mechanical in its working.

To sum up and conclude. The psychologist claims scientific freedom to study and state the facts of psychology as he finds them. He is dogmatically forbidden to do so, on the ground that to do so leads to the denial of the law of the conservation of energy. The question which I wish to put to the Society is this: does that law require us "to assume that the quantity of energy in the universe is finite; and that, being finite, it neither increases nor decreases?"*

* J. Ward, *Naturalism and Agnosticism*, ii., p. 75.

Mediæval Drama in France before the Fourteenth Century.

By W. E. Urwick, M A.

[Read May 23rd, 1901]

As its title indicates, it is the purpose of this paper to trace the origin and early history of French mediaeval drama, so far as the sparse documents on the subject that have survived allow. The subject naturally falls into three parts: (1) the liturgical origin of the plays; (2) their development in the hands of the clergy; and (3) the gradual transfer into the hands of lay societies. Until this last stage is reached it is hardly accurate to speak of this movement as French Its language up till then is Latin, and in tracing its early history we shall be in reality dealing with a geographical section of European religious literature, for a parallel and contemporaneous development was taking place in the Church world of Northern Italy, Germany, Holland and Spain certainly, and in all probability in England and Ireland also. But France, and more especially northern and north-west France, appears to be its earliest home, and there are two distinct advantages in studying it in relation to French literature one, that, whereas in all other countries except Germany there are hardly any documents from which to piece together an account, in France a considerable number of Latin dramas of different dates have survived; and the other that, as a part of French literature, a good deal of light may be thrown upon it by comparison with the epic and lyric movements which had preceded it, and were already approaching their decadence before drama had found a home outside the precincts of the church and monastery.

Survivals in France (and elsewhere also for that matter) have certain characteristics in common which it is well to

state before approaching any of them in detail. With the exception of the three of Hilarius they are all anonymous; they give no indication of the date of the composition of the drama or dramatic scene. The date of the MSS. itself is no sure guide, for some of the earliest forms of a given play are often found in thirteenth, fourteenth and fifteenth century manuscripts, and earlier forms naturally often continued to be used in many centres long after a more elaborate form had been composed in one centre. All without exception were set to music throughout and none were ever performed without the music; in by far the majority of cases the music accompanies the words in the MS., and in those where it does not there are distinct directions that the parts should be sung. Naturally such performances presuppose a full choir and, apart from scenic accessories gradually introduced, could only be performed in the richer foundations, and there their introduction or omission was optional and the amount of elaboration in the performance would vary from time to time with the taste and proclivities of the authorities. So far as France was concerned, if we may take the MSS. as a guide, the chief centres where liturgical and semi-liturgical drama was cultivated were Limoges, Rouen, Arles, Saintes and St. Benoit-sur-Loire.

The movement was absolutely spontaneous and throughout its whole development completely uninfluenced by classical models. Mediaeval drama can claim to be as natural an outgrowth from the services of the Church as was Greek drama from the religious rights of Dionysus. When classical influences did make themselves felt in France during the sixteenth and at the beginning of the seventeenth centuries, so far from fostering or transforming the religious drama, which had then become the national French entertainment, they combined with other causes to stifle it completely. This was not the case either in England or in Spain, but in France the Renaissance marks a complete break in the history of tragedy, and modern tragedy springs as surely from classical influences as mediaeval drama does not.

The subject has already been divided into three periods. These are not, however, chronologically distinct The first, the rise of liturgical drama, dates roughly from some time in the ninth century to the end of the tenth. In the eleventh and first half of the twelfth century, in which the plays became especially popular among certain rich centres of the Church, liturgical drama and semi-liturgical drama -*i e*, plays which gradually expand and become detachable from the office of the day—exist side by side, and there is a tendency to introduce short passages in French side by side with Latin From towards the end of the twelfth century dates the earliest complete play in French, "Le Drame d'Adam," and slightly later comes "Le Jeu de St. Nicholas" of Jean Bodel. The thirteenth century gives us nothing beyond "Le Miracle of Théophile" by Rutebeuf, for the work of Adam de la Halle belongs to the development of comedy and therefore lies outside the scope of this paper. It must not, however, be supposed that the composition or performance of Latin dramas ceased when performances in the vulgar tongue began. Composition of semi-liturgical dramas continued in France till the close of the thirteenth century and then ceased, though in Germany composition probably went on longer, and performances in churches and as part of the services of Latin dramatic scenes, both in their simplest and in the later more elaborate forms, persisted for centuries after the close of the period with which this paper deals. Thus till the eleventh century there is no sign of anything but purely liturgical drama; during the latter half of the eleventh to the middle of the twelfth century liturgical drama and semi-liturgical drama ran side by side, and then French lay (religious) plays are added and all three continue till the end of the fourteenth century and beyond it; only in France no new dramas were composed in Latin after the close of the thirteenth century.

In a certain sense there is a dramatic element in all religious ritual, and germs of drama existed in abundance in the elaborate ritual which was the heritage of the Church in the Middle Ages. And the æsthetic delight of pious

monks in its performance, combined with the simple and unquestioning faith of a people who looked to the Church for the satisfaction of all those longings which the cruel hardships of their life could only intensify, gave rise to a movement, at first apparently musical and afterwards literary, to lengthen and further elaborate church services, on the lines already laid down This movement, for which no certain dates can be given, had already started in France in the ninth century and spread thence towards the close of that century to St Gall in Germany The off-growths from the ritual which thus arose are called tropes, and of these some were in the form of dialogue, and of tropes in dialogue some again grew into short dramatic scenes. Tropes in dialogue were in prose—not verse, and prose is the earliest form of the dramatic scene All tropes were of course choral, and it is thought that those in dialogue were performed first of all merely as antiphons by the choir without dramatic action, though there does not appear to be direct evidence of such a stage There can be no doubt, however, that the tropal movement, the literary and musical remains of which only survive, was accompanied by an elaboration of the scenic side of the service, though the details of such development are untraceable in their earlier stages Three dramas of the Middle Ages, all of them destined to undergo an enormous development later, are distinctly traceable to the stage when they were merely short tropes. The first is the drama of the Shepherds, the second, the drama of the three Maries' visit to the Sepulchre, the third, the Prophets of Christ. The first and the third arise from tropes to the Christmas festivals, the second from a trope to the festival of Easter. The second is the kernel from which by gradual elaboration the Passion plays arose, the first gave rise to all the series of Natavity plays, and the third to the whole cycle of Old Testament plays There is no evidence to show that any but these three plays originated in a prose trope and passed thence through intermediate stages to their ultimate form, nor is it either necessary or reasonable to suppose that they did, as will appear in the sequel. Hence the statement that liturgical

drama originated in the trope is true, but only in a limited sense.

The limits of this paper make it impossible to trace all three of these scenes through intermediate stages. An almost complete list of the manuscripts of the three Maries' scene has been collected from available sources in Lange's "Lateinische Osterfeirn," and they are arranged in a probable order of their origin. Their number (224), of which Germany contributes 150, France 52, Italy 7, Spain 2, and England 1, apart from proving the immense popularity of the scene, indicates perhaps that Latin drama was far more cultivated in France and Germany than elsewhere, but on that point it is difficult to dogmatise, for many causes contribute to the survival or disappearance of MSS., and there is one MS., at any rate, in Dublin of an advanced stage of this scene which Lange did not know, and others may exist, especially in Italy and Spain. Curiously, of all these MSS. the two oldest come, one from Germany (Bamberg) and the other from England.* Both are of the tenth century and yet both contain slight additions to the original four-lined trope. The one from England is accompanied by the earliest scenic directions of mediæval drama; in the MS. these have an Anglo-Saxon gloss and are worth translating. "While the third reading is recited let four brothers robe themselves. Let one of them, robed in an alb, start and secretly approach the place of the sepulchre and there, holding a palm in his hand, sit quiet, and while the third response is sung let the remaining three approach, all indeed wearing copes and bearing censers with incense in their hands; and step by step, as though seeking something, let them come before the place of the sepulchre. For these things are done in imitation of an angel sitting on the monument and of women coming with spices to anoint the body of Jesus. When therefore the one sitting has seen the three, as though at a loss and seeking something, approach, let him begin in a moderate and sweet-sounding voice to

* *Regularis Concordia* of St Ethelwold, Brit. Mus., Cotton. Tib. III. A., f. 21, *a* and *b*.

sing 'Quem quæritis?' etc.; which having been sung to the end, let these three answer with one voice, 'Jesum Nazarenum,' to whom they, 'Non est hic, surrexit, sicut prædixerat, ite nuntiate quia surrexit de mortuis.' At the voice of this order let the three turn to the choir, saying, 'Alleluia, surrexit Dominus de sepulcro.' This said, let him, again sitting, as though calling them back, say the antiphon, 'Venite et videte locum,' etc. Saying this, let him arise and raise the veil and show them the place bared of the cross and only the cloths lying in which the cross had been rolled. Which having been seen, let them place the censors which they bore on the same sepulchre and let them take the linen and stretch it out towards the clergy, and, as though showing that the Lord had risen and was not wrapped in it, let them sing the antiphon: 'Surrexit Dominus de sepulcro,' and let them place the linen on the altar. The antiphon finished, let the Prior, rejoicing for the triumph of our King, for that he had conquered death and risen, begin the hymn 'Te Deum laudamus.'"

Here, as throughout our period of mediæval drama, the parts were all played by men or boys, never by women, (except perhaps in a convent). This scene from the tenth century in some monastic church is the earliest of which there is record, and it is not the simplest form of the trope—that lacks the phrase, "Venite et videte locum" All through there is no mention of the attendant worshippers—the congregation; the whole scene is for the edification of the officiating choir and clergy. This is worth noting, for many writers speak as though in its origin liturgical drama was definitely intended to instruct, edify and delight the people. There is no ground for such a view. These scenes arose, like the tropes themselves, from the delight of the clergy in their services, any idea of spectacular education of the people is later and quite secondary. The reference to the sepulchre bared of the cross and the cloths in which the cross had been wrapped shows that this scene was the complement of another on Good Friday, when the cross had been solemnly placed in the sepulchre (permanent or figured

monument at this early date is uncertain). I have not been able to find any reference to this custom, so prevalent later, as early as this one, and there is no trace of a dialogued trope for the Good Friday "officium sepulcri," it was perhaps performed to the singing of a sequence. It is evident that Easter figurative scenes stood in close relation to those of Good Friday; which of the two is earlier, whether the burial of the cross suggested the resurrection scene or *vice versa*, I do not know.

The Resurrection scene in this primitive form is found in forty-five MSS. varying from the tenth to the fourteenth centuries All agree in containing word for word the four sentences of the original trope taken from the accounts in SS Mark and Luke- not from the gospel of the day Mone held the view that some unknown monk had composed this trope definitely as a dramatic scene, that its performance was dramatic from the outset, *i e*, that liturgical drama sprang suddenly into being as drama Lange shows this view to be untenable by quoting a trope from Limoges (eleventh century MS) on the Ascension, which is in dialogue exactly almost verbally on the lines of the Resurrection trope, yet which was sung by the choir only and did not give rise to a dramatic scene. The controversy on this point, which is of importance, for the origin of liturgical drama, is reviewed by Mr Pierce Butler in "An English Miscellany"; but in that article, though in all other respects it is a *résumé* of Lange's argument, Mr. Butler makes no reference to the existence of this Ascension trope on which Lange's contentions mainly hinge. Lange's treatment conclusively proves that the Easter dialogued trope was first merely sung by the choir without dramatic action, and yet in the tenth century the dramatised, *i.e*, the second stage had already been reached.*

The remaining stages through which this scene passed as liturgical drama must be briefly summarized: they are (1)

* It is noteworthy that the existence of this tenth century English MS. is difficult to reconcile with the still oft repeated statement that there are no signs of religious drama in England before the Norman Conquest. Mr. Pollard still includes this statement in the introduction to the third edition of "Early English Miracle Plays."

the introduction of further antiphons, already contained in the ritual, as part of the scene; (2) the further addition of the second part of the sequence "Victimae pascali laudes"—which was already in dialogue; (3) the introduction of the running of the apostles to the sepulchre—the germs of a new scene, with, in some MSS., the addition of an anthem sung by choir and people, "Christ has risen from the dead"; (4) the introduction of the appearance of Christ to Mary. This is found chiefly in German MSS. (four only are French, two from Rouen, one from Orleans and one from Mont St Michel). None of these MSS are earlier than the thirteenth century.

There is very considerable variety of treatment in the MSS. of the third and fourth stages, and though the original part appears in prose metrical sequences are included. The introduction of metrical sequences is interesting because it forms a bridge between prose and metrical Latin drama, and it shows that the tropes were further used for purposes of amplification of dramatic scenes. The stages here mentioned are worked out by Dr. Lange. An interesting example, not mentioned by Lange, of the use of the sequence in enlarging the scene is an MS. from Archbishop Marsh's library in Dublin, a facsimile of which is given in Mr. Frere's Winchester Troper, where the scene is introduced by a sequence sung by the three Maries, bewailing the death of Christ

On Easter Monday it became the custom to celebrate a scene of the appearance of Christ to two disciples going to Emmaus. A form of it is preserved in an MS (fourteenth century) of Saintes. It is mentioned here because it illustrates a common way in which, after the idea of such scenes interpolated into the service had become familiar, new scenes originated. It is a semi-dramatic version of the Gospel of the day. That is to say, our Lord and the two disciples are represented by priests, and the dialogued part of the Gospel is put into their mouth, while the narrative part is sung by the choir. This would be nothing but a choral rendering of the Gospel, only that

the MS. includes simple directions for action. In another fourteenth century MS these are more elaborate * Two priests of the second rank were the pilgrims, clothed in tunics, with beards, and carrying staff and purse They advance slowly by the right aisle to the western door and stop at the head of the procession. The priest representing Christ, clothed in an alb and amict, a cross on the right shoulder and eyes lowered, approached them. The dialogue is in Scripture words. A tent raised in the nave represents the *mansion* of Emmaus—the breaking of bread took place in the tent and the Christ disappeared. Then the procession re-formed and proceeded to the choir, where Vespers were finished. To this scene again, in an MS of St. Benoit, is added another of the appearance to the apostles, Thomas being absent--the choir represent the apostles. Thomas joins the apostles and the Christ appears again.

The twelfth century gives us another glimpse of the Resurrection plays, not in Latin drama but in French. The manuscript† that preserves this precious fragment (though 360 lines it is only a fragment) is fourteenth century, but the language speaks for the twelfth century Putting aside all questions connected with the transition from Latin to French drama, I here merely summarize what it adds to our knowledge of the early stage. It is all in octo-syllabic verses and the dialogue is broken by short narrative verses to piece together the different scenes. It begins with the request of Joseph of Arimathea for the body of Christ addressed to Pilate. Pilate consents and expresses regret for having condemned him. Then follows the legend of blind Longinus, whose sight was restored by the blood flowing from the Saviour's side, the descent from the Cross and the burial, and the posting of guards by the sepulchre. Here the fragment ceases, but a rhymed prologue describes the *mise en scène* and gives an idea of the dimensions of the whole. There is to be a crucifix and a monument, a gaol for

* Rouen MS , No. 4,829.

† *Bibliothèque Nat. Paris*, 902, fonds français, ed. Jubinal, 1834. 8vo. Paris.

prisoners; hell is to be on one side of the stage, and paradise on the other and the following *mansions* are mentioned: one for Pilate with six or seven knights as vassals, another for Caiaphas and the Jews, one for Joseph, one for Nicodemus, each with his people. The fifth mansion is for the disciples, the sixth for the three Maries and finally there are to be places representing Galilee and Emmaus. The play evidently began after the Passion and recounted Scripture history in a succession of scenes, including all those hitherto spoken of until Christ's appearance after the Resurrection in Galilee The stage, which had to find room for a row of six mansions (or *estals* (stalls) as the prologue calls them), for two figured places, and for paradise and hell, must have been almost as elaborate as any in the fifteenth century.

Here we must leave the Easter plays—they disappear completely from sight in French documents for two centuries, when they reappear in the vast New Testament cycles of the fifteenth and sixteenth centuries. There they are of course far longer and are preceded by Passion plays, of which, beyond the dirge of the three Maries and the apparently mute office of the sepulchre, there is no trace in France before the fifteenth century. M. Petit de Julleville is of opinion that French writers long hesitated to represent the Passion of our Lord. The gap between the French-Latin Easter drama of the thirteenth century and the vast French Easter mysteries of the fifteenth might be partly bridged from English and German sources, but these lie altogether beyond the scope of this paper.

The drama of the shepherds is another centre round which Nativity plays grew up. It is traceable to a dialogue trope very similar to the Resurrection trope already mentioned and exceeding short:—

> "*Quem quaeritis in praesepe, pastores, dicite.*"
> Respondent: "*Salvatorem Christum dominum infantem.*"
> "*Adest hic parvulus, cum Maria matre sua.*"
> "*Et nunc euntes dicite quia natus est. Alleluia.*"

Apparently the oldest form that has survived is that pre-

served by a fourteenth century Rouen MS.* Here are its rubrics:—Before the *Introit* let the cradle be placed behind the altar and the image of the Virgin placed there. First let a boy before the choir, in a high place, announce the Nativity of the Lord to five canons or their vicars of the second rank The shepherds enter by the great door of the choir and cross the choir in the middle. The boy says to them the verses from St. Luke (ii., 10-12) Several boys in the vaultings of the church, figuring angels, sing in a loud voice, "Gloria in excelsis." The shepherds advance toward the cradle chanting "Pax in terris." Two priests of the second rank clothed in dalmatic, figuring midwives by the cradle, show the infant Jesus to the shepherds, who worship and retire chanting "Alleluia." "Then let Mass begin and let the shepherds direct (*regant*) the choir."

There are other more developed forms, where one of the shepherds is to read the lesson or two of them to sing the Gradual. The appearance of apocryphal midwives shows that this form even is comparatively late, but intermediate ones are lost. Not developed by a trope, but probably suggested by the office of the shepherds, is the Drama of the Magi at Epiphany, and, similar in character, the Drama of the Annunciation; both exist in a simple form in prose and a more complicated form in verse, following the regular development.†

The early dramatic scene of the Prophets of Christ is

* Du Cange, *v. sub* "Pastorum Officium"

† Both are an interesting study, but must be passed by. One fact about the Adoration of the Magi is worth noting specially A fragment of an eleventh century form was found on the flyleaf of a psalter of Charles the Bald, and this fragment is found again word for word in one of the latest and most developed forms of the play (an MS. from St Benoit). This shows the way in which one version made use of another. About the Annunciation play it is worth noting (1) that in playing it at Civitadale the procession left the church and proceeded to the forum (public square) singing the response "*Gaude Virgo Maria*", then *evangelium cantatur, cum ludo*, *i.e.*, both gospel and play were sung This done, they return to the church. (2) At Tournay a canon of the place had left a bequest to be spent on performing the Annunciation periodically. The scene was called the Golden Mass and interpolated into the office of the day. These dramas originate apparently from the gospel of the day, but are not traceable so far back as either the Resurrection scene or the scene of the Shepherds. (See P. de Julleville, *Les Mystères*, vol. i., p. 30.)

undoubtedly the origin of the whole Old Testament cycle of plays, and its history can be fairly completely traced in French-Latin sources and in them only.* Among the interpolations into the service for elaborating the Christmas festival was a spurious sermon of St. Augustine (Sermo beati Augustini de natali Domini). The sermon exists in a twelfth century MS., a breviary from Arles (the liturgy of it is much older) preserved in the Paris National Library, where it is called Lectio Sexta. St. Augustine, addressing the Jews, appeals to the prophets as witnesses; Isaiah, Jeremiah, Moses, Daniel and David, then Simeon, Zachariah and Elizabeth, passages from the words of each being quoted. Then, turning to the Gentiles, he calls on Vergil, Nebuchadnezzar and then Sibyl, with twenty-seven hexameters from Vergil: the verses "Jam nova progenies," from the fourth eclogue are introduced. This sermon, already quite dramatic, gave rise to a dialogued trope at an unknown date. The earliest form of it is in a Limoges troper.† It was sung after Tierce or after Matins to prolong the office. The monks in two rows took the prophets' parts, the precentor the part of St. Augustine. The prophets are the same as those in the sermon, but Habakkuk and John the Baptist are added. Their prophecies are metrical versions of the quotations in the sermon. The Gentile hexameters are improved upon; Vergil's line, for example, becomes *Ecce polo demissa solo nova progenies est.* At a later but uncertain date the scene reappears at Rouen in a dramatic and enlarged form.‡ Balaam is introduced—he and his ass were destined to contribute much to the comic element in the fifteenth century. The directions for costumes and scenery are elaborate. Nebuchadnezzar has his throne and a crown on his head; the part is enlarged; a furnace (*Linteo et stuppis constituta*) is provided in the nave; three young men are to walk about in it and Nebuchadnezzar is to admire;

* *V.* Sepet, *Le drame crétien au moyen âge*, and P. de Julleville, *op. cit.*

† *Bibl. Nat.*, 1139.

‡ *V.* Du Cange, *sub* "Festum Asinorum."

Moses in alb and cope "with horns and a beard" carries the tables of the Law; Isaiah has a red star on his forehead; Aaron wears a mitre and holds a flower; Daniel in a green tunic is armed with a pike. Habakkuk, very old and lame, carries a wallet full of roots, which he pretends to eat, and a whip "wherewith he may shake the nations." John the Baptist has bare feet and carries the Gospel; Elizabeth, clothed in white is to appear *quasi prægnans*, and Vergil is to be a young man, *bene ornatus*. The whole procession marched from the cloisters round to the western door of the church and up the nave as far as the furnace; six monks representing the infidel Jews stood on one side, six infidel Gentiles on the other. Evocatores or heralds called on the performers each in turn, and after each had come forward and sung his metrical prophecy the choir like a Greek chorus apostrophized the six Jews and Gentiles—

> "*O Judaea incredula,*
> *Cur adhuc manes inverecunda?*"

Vergil and the Sibyl came last, and when all was over the whole procession reformed and proceeded to the choir for Mass. This play is scarcely semi-liturgic; it is not interpolated into, but played before the office of the day. When drama had reached this stage, it was time for it to leave the church; it is no wonder that some of the worshippers who witnessed such performances began like the Greeks to ask, "What has this to do with Dionysus." In a sense the whole Reformation movement was a continuation of the cry.

Obviously, as it expanded, this drama began to get too long for a single performance. The first of these prophets honoured with a complete drama to himself, which has survived, is Daniel; and there are two plays, both fourteenth century, on Daniel—one by Hilarius, the other anonymous; both are elaborate. The dramatis personæ of that by Hilarius are: first part, Belshazzar, the queen, Daniel, four soldiers, some lords; second part, Darius, Daniel, the same soldiers, and lords, three angels, a den for lions, lions in the den, Habakkuk. The first part includes a feast at

Babylon, when Belshazzar desecrated the sacred vessels; a chorus in the king's honour; the appearance of the words *Mene*, etc.; the entry of the queen; the failure of the wise men to interpret the words; the entry of Daniel, summoned by advice of the queen; his interpretation; and closes with a chorus in honour of the queen. The second part (we might almost say act) includes the arrival of Darius with his army (*i.e.*, the four soldiers); the slaughter of Belshazzar and chorus in honour of Darius; Daniel appears, refuses to worship the King and is cast into the lions' den; an angel brings him Habakkuk; Daniel is justified and received into favour.

Hilarius' version, 300 odd lines, is all in Latin syllabic verses. It was to be represented "ad matutinas" or "ad vesperas." At the end of the play Darius was to start the "Te Deum" or the "Magnificat," according to the time.

The other edition emanates from Beauvais and is a monastery piece composed by clerks and students. This is interesting, for it suggests the idea that, besides delight in long musical services, and later a desire to edify the congregation, the use of such exercises in educating students, clerks and others both in Latin and in Scripture may have been one of the motives for the spread of the movement.

The Beauvais Daniel is an example of those plays of about the same date (viz., middle or close of twelfth century) in which passages occur in French—short tags in this play, as though to eke out a verse. In two of the three plays of Hilarius the same thing occurs rather more extensively: one on the raising of Lazarus, and there it is a pathetic refrain of Martha and Mary; the other a miracle of St. Nicholas. Another instance is an older play than any, a half-lyrical and pathetic rendering of the Parable of the Ten Virgins, in which about one third is in a mixed dialect of Langue d'oïl and Langue d'oc. This play is ascribed by Mr. Pollard to the thirteenth century. It is true that the MS. is thirteenth century, but it contains documents of different dates bound together, and some French authorities place the date of the Sponsus (as the play

is called) as early as the tenth century, while all agree that it cannot be later than the eleventh. It seems to belong to a class by itself and, so far as introduction of French is concerned, to have been long in finding imitators.

This introduction of little smatterings in French, in plays otherwise all in Latin, is an unexplained problem.

Where the whole was sung a few French words could not have served to help the people to follow; even had they heard the words, they are mostly such as could not possibly convey even a thread of the story. The French words are put indiscriminately in the mouths of angels, common people, chief characters and minor characters. It seems impossible to suggest a reason for them. It is usually said that they pave the way for the drama wholly in French. This is at best a hypothesis and there is little to support it. It is often stated that as time goes on these passages grow longer. That is not the case, in French sources at any rate; it is only made to appear probable by placing the "Sponsus play" a century and a half after its probable date. The fact is that the date at which plays were first composed wholly in French is unknown; the date given to the earliest known is the latter half of the twelfth century, *i.e.*, about contemporary with those of Hilarius. The date cannot be precisely fixed within fifty years. This "Drame d'Adam," together with the "Nicholas" of Jean Bodel, and a fragment of a resurrection play, are evidences that before the end of the twelfth century a purely French drama existed. How long it had existed, how many other plays accompanied or preceded these is unknown. It is quite possible that little pieces of French in Latin drama, almost macaronic in character, were a reflex of already existing French drama and in that case we should have to look elsewhere for the idea of a drama completely in French. It may perhaps have been suggested by the *épître farcie*, *i.e.*, Scriptural verses paraphrased and amplified in French, the Latin phrase and the French metrical rendering of greater length alternating, many examples of which have survived. This thesis, which is a subject for a paper in itself, can here be no more than mentioned.

Before leaving the subject of Latin drama to go on to those few French plays which lie within our period, it may be well to summarise the main outline of growth under exclusively Church influences.

Latin drama is choral throughout; (1) its earliest form is prose and it sprang from dialogued tropes first sung by the choir only without action; (2) then solos took the place of merely antiphons; (3) then simple action was added, and with it came fresh phrases still in prose and at first in purely Scriptural words; (4) next comes a stage in which the prose is abandoned and Latin metrical syllabic verse (*i.e.*, based on popular not classical metres) takes its place. Here for the first time some scope is given for originality on the part of an author. This stage began probably at the close of the eleventh century; the scene, up till this of the briefest character (five to forty lines), is enlarged by absorbing into itself parts of sequences already in verse. The metrical nature of such sequences may perhaps have suggested the recasting of the previous prose into a metrical form.

Both tropes and dramatic action were first introduced to enhance the solemnity of Easter celebrations, and the scene of the three Maries alone can with any certainty be said to have passed through all these stages. The Nativity scene of the shepherds certainly originated in a trope, but intermediate stages are not traceable, the earliest MS. dating from the fourteenth century, though of course the contents may be far older. The Prophets of Christ, also a Christmas scene, starts from a trope (preserved in the already mentioned twelfth century Limoges troper), but this trope is not drawn from Scripture but from Augustine's spurious sermon (the distinction between sacred and canonical texts was vague in the Middle Ages).

With the dramatic scenes of Christmas and Easter as central points, a double development went on. The scenes themselves were enlarged by additions and extension, and the example set by them was imitated at other Church festivals, in which case the material is usually drawn from the gospel of the day.

Internal expansion has already been illustrated both in the case of the Prophets of Christ and the Three Maries' scene. Extension of the idea to other services led to dramatic representation of the Annunciation, the Adoration of the Magi, the Slaughter of the Innocents, the Flight into Egypt, the Parable of the Ten Virgins, the Resurrection of Lazarus, the Conversion of St. Paul, and four Miracles of St. Nicholas.

It is interesting to find these Latin plays subject to what the French call the "law of amplification." For the observance of this law is one of the most striking characteristics of all French mediæval literature; the best examples of it are the vast growth of poems of national epic and of Arthur romance. But in the case of Latin drama it was hampered in its action throughout by the intense conservatism of the Church. Another most striking characteristic of mediæval poetry is its cyclical character, and cyclical tendencies were at work on mediæval drama, even whilst it was exclusively in the hands of the Church. Almost all the plays found a common bond in their connection with the life of Christ which the Church year illustrated, and as in their growth they gradually became disconnected with the particular festival on which they were originally performed, they tended to group themselves together. The best example is of German origin. It is preserved in a thirteenth century MS. of Munich. It begins with the Prophets of Christ, presided over by St. Augustine in person (among the prophets Balaam appears on his ass), goes on with a dispute between Augustine and the Jews as to the possibility of the Incarnation, then represents the Annunciation, the visit of Elizabeth, the Incarnation, the Adoration of the Magi, including their visit to Herod, the shepherd's scene, the Slaughter of the Innocents, the death of Herod (who is seized by demons, *multum gaudentes*), and the Flight into Egypt, and ends with a scene in Egypt, where idols fall before the infant Christ and cannot be raised again and the king of Egypt finally worships the Christ and has the idols broken—all this consecutively. The cyclical character is apparent—the bolder

flights of German imagination and the tendency to a type of realism, which French-Latin drama had too much delicacy to imitate, are no less apparent. St. Augustine's presence to conduct the Prophets' scene is a striking proof of the origin of the Old Testament cycle.

Throughout, Latin drama was performed in the church, at first in the choir, then, as the scene developed, in the nave; when interpolated in the service it takes place before the Introit; in its more developed form it precedes the service altogether. I do not know of any French example of a performance in the churchyard, though in one case, that of Civitadale, the public square was the theatre.

In passing from Latin to French drama falling within this period it is most important to bear in mind that one reason why drama originated in the church was that the Church was long the only corporation existing capable of its performance. Drama differs from other kinds of literature in demanding the close association of a number of people prepared to work together, some suitable place for its theatre, and an audience to witness it. All these the Church had from the outset. Court societies might have taken it up, had they not been so enamoured of court love themes and Arthur romances; but until there was some kind of organization, with literary tastes and ambitions, and existing too in a centre large enough to command an audience, there could be no French drama. Hence the question of the date of the origin of French mediæval drama is connected with another equally obscure, namely, at what date did literary associations arise in the French communes? For it was in them, and in them only, that both the population, the enterprise and the accommodation necessary for dramatic performance could be found. In the fifteenth century onwards mediæval drama was, in France as in England and Germany, in the hands of trade guilds. How long it had been in their hands is quite uncertain, and the date when trade guilds first arose is equally uncertain. But whether before trade guilds or not, certainly concurrently with them, there existed in the flour-

ishing communes of northern France societies half-religious and half-literary, called Puys.* The most famous of these societies, which were always under the protection of some patron saint and in many cases had a taste for pious literature, is the Puys of Arras, which claimed to have been founded by the Virgin Mary herself in 1005, but which M. Petit de Julleville thinks was founded sometime in the twelfth century. And one of the three surviving plays written before the fourteenth century, the "St. Nicholas" of Jean Bodel was in all probability written for the Puys of Arras. Another of them, the "Miracle de Théophile," by Rutebeuf, may have been written for a similar society, but that is more doubtful. Of the theatre of the fourteenth century forty-three plays have survived, all miracle plays, and forty-two of them miracles of the Virgin Mary, and these all emanate from some Puy or Puys, though it is unknown which. As to whether the Puys performed French plays on Scriptural subjects already treated of in Latin drama or not, there is no direct evidence. That they did so, is an inference drawn from the fact, that when they appear in the vast cyclical collections of the fifteenth and sixteenth centuries, they have not only enormously expanded and completely detached themselves from the Church services, but have also admitted a large inroad of the comic element. These changes did not take place under direct Church auspices, for the Church continued to perform in Latin the older and simpler forms. They could therefore only have been the work of the Puys and later the trade guilds of the communes. But there still remains the question, how comes it that, with the exception of the "Jeu d'Adam," and the fragment of a Resurrection play, all relics of French drama previous to the fifteenth century should be miracle plays, none of them on Scriptural subjects? The only answer available is that more care was taken by the Puys of plays on new subjects, and therefore regarded as original, than of those on older Scriptural subjects which the Puys only gradually enlarged.

* (The word means mountain and is said to designate the raised platform on which the members gathered to read or sing their compositions.)

It is impossible at the close of an already lengthy paper to do anything like justice to the four French dramas of the twelfth and thirteenth centuries; as the earliest remnants of French drama they have all been at length treated in several French monographs.

All questions of language and style and detailed content must be left on one side, and I shall only shortly indicate the connection of one of them with Latin drama. The "Jeu d'Adam" is preserved in a single twelfth century MS. in the Tours library. There is absolutely nothing to indicate its date, or place of origin, or author. It may or may not be a French edition of a lost Latin play. French-Latin remains have no Adam scene. It is in reality a three-act drama. The first act consists of God's command to Adam and Eve in the garden, the temptation of Adam by Satan, the temptation and fall of Eve and then of Adam; their lamentation and expulsion from Paradise, their tilling the ground and sowing, while the devil sows tares behind them, and finally, their exit to hell, escorted by demons (587 lines). The second act shows Cain and Abel sacrificing, Cain's slaying of Abel, God's curse of Cain, and finally, the exit of both to hell (154 lines). The third act is the procession of Prophets announcing the Christ (200 lines). This last act is one further proof of the origin of the Old Testament cycle. Finally comes a sermon, all in French (360 lines), which ends by enumerating the fifteen signs of the last judgment. The rubrics or stage directions are unusually elaborate, all in Latin, and so full of interest that to do them justice they ought all to be given in full. The following points, however, are of special importance. Paradise is to be on a raised platform, surrounded by drapery and silk hangings, of such a height that only the head and shoulders are to be seen. "There shall be seen there sweet-smelling flowers and foliage, diverse trees with fruits hanging to make the place appear more pleasing." The author is very particular about articulation and gesture. "Let Adam be well instructed as to when he shall answer, so as not to be too quick or too slow. Let not only him but all the personages

be instructed to speak deliberately and to make suitable gestures to what they say, let them not add or omit a single syllable of the metre of their verse, but let all pronounce firmly and say in order all that is to be said." In the temptation of Eve a serpent cleverly devised is to mount the forbidden tree and Eve is to approach and give ear to it. When driven out of Paradise, Adam with a spade and Eve with a rake, shall begin to cultivate the ground and sow corn. Having sown they shall sit a little aside as though weary with work and "shall often raise tearful eyes to Paradise and strike their chests." Meantime the devil shall come and plant in their field thorns and tares and then shall depart. When Adam and Eve return and see the thorns and tares already raised, pierced with violent grief, "they shall fall on the ground and, remaining lying there, shall strike their breasts and thighs, making gestures of grief."

When Adam and Eve are to be conducted to hell, "there shall come the devil with three or four devils with him carrying chains and collars of iron, which they shall place on the necks of Adam and Eve. Some shall push and others shall drag them towards hell. At the entry of hell other devils shall come and meet them dancing with joy together for the fall of Adam and Eve . . . They shall place them in hell, whence they shall make issue great smoke and shall utter loud cries of joy, they shall clash their kettles and pans so as to be heard outside, and after a while some shall come out again and run here and there (*discurrant*) through the rows (*plateas*) while others remain in hell." When similarly taking off Cain and Abel, "they shall overwhelm Cain with blows but take Abel more quietly." When the Figura, *i.e.*, God, has finished his part he is to retire to the church (*vadat ad ecclesiam*). This has been held to prove that the play took place in the churchyard, but the words would do equally well if it had been played in a monastery. It is the only evidence which I have met with of a churchyard stage and it is rather too slender to support the theory that the churchyard formed an intermediate step between the church

and the public square. In the prophet scene nothing is new except the language. The prophets ready waiting in a hidden place are called up by a lector in the words of St. Augustine's sermon, "Vos convenio Judœi." Virgil and the Sibyl do not appear.

Apart from the stage directions, Latin still appears in this twelfth century play in two directions: choruses in Latin by a choir, not the actors, are introduced at the end of the Adam and Eve scene and at the end of the Cain and Abel scene. These might perfectly well be omitted so far as the unity of the performance is concerned, but they are a distinct bond between this the first play not sung and previous and contemporary Church wholly musical drama.

Further, in the "Jeu d'Adam" there are short Scriptural texts in Latin at the head of many of the speeches, the speeches themselves are an enlarged and free French metrical version of the text. Whether in playing these texts were read by a lector or sung by the choir or omitted altogether is uncertain. These texts, besides being a bond between Latin and French drama, are, I think, of great importance to the question of the origin of purely French plays. The method adopted in this the earliest French play is almost exactly that of the *épître farcie* which has already been mentioned.

The French metrical sermon which follows the play is an early example of a custom, very common in latter plays, of ending the performance by an exhortation, which takes the place of the usual "Te Deum" with Mass of liturgical drama. This twelfth century sermon includes the following lines:—

> "He (*i.e.*, the French public) would rather hear sung
> How Rolland went jousting
> And Oliver his comrade,
> Than he would list to the Passion
> Which Christ suffered in great woe
> For the sin which Adam did."

Here we have an indication of how French mediæval drama at the outset found in old national epic a rival to its

popularity. It is interesting to note that the earliest MS. of the Song of Roland is within a few years a contemporary of the " Drame d'Adam " and written in the same Norman dialect. Great as was the popularity of epic in the twelfth century, drama was destined to outlive epic by three centuries and become not only the most universally popular national entertainment which the French have ever had, but also a concrete expression of the only theory of life and the world which the mediæval mind could conceive—a world above which was a concrete paradise of God, saints and angels, and below a concrete hell of devils and lost souls, a world which was a literal theatre, where hell and heaven met continually and strove for men. The mediæval mind looked out upon this world through eyes that saw a miraculous blending of heaven and hell in every event which rivetted its attention. It is usual to speak of the religious stage as symbolizing these beliefs, but it is almost truer to say that the mediæval stage held up a mirror before the mediæval mind and reflected it, and the reflexion is true even to those grotesque and comic traits which shock modern sensibilities. The Church, it is true, had so far excluded these elements, but they make their appearance in the earliest French play, *i.e.*, as soon as composition is freed from restraint. It is impossible to say whether an emotion of horror or amusement would predominate with the audience, which witnessed the devil's performances in the "Jeu d'Adam." The juxtaposition of the grotesque and the tragic which was destined to become one of the main characteristics of mediæval drama, appeared no more incongruous on the stage than in the stone ornamentation of a cathedral. The grotesque is the expression of the French *esprit moqueur* as much as the tragic is the expression of French faith, and the mediæval stage is a theatre of a long conflict between the two elements, in which the tragic gradually succumbed. It was not science, nor classical learning, but this *esprit moqueur*, which killed religious drama, just as in the larger theatre of life it gradually undermined the mediæval faith.

From a mere musical addition to a church celebration in the ninth and tenth centuries, drama had already in the twelfth century, as the "Jeu d'Adam" and the fragment of the Resurrection play prove, undertaken to represent on a single stage the relation of three worlds, and the purpose and destiny of the then known universe, and the process of its development had been quite unconscious. Add the Resurrection cycle to the "Jeu d'Adam" and you have all the essentials of the vast fifteenth century compilations. Subsequent generations elaborate everywhere, add a scene or two here and here, but introduce no new idea either in stage mountings or in plan. They mainly develop minor characters, all of them French and nearly all humorous—soldiers, executioners, and merchants, whose frivolous attitude in the midst of portentous events makes mediæval drama all the truer picture of the minds which it reflects. They expand the twelfth century outlines at enormous length—one single edition occupies six thick octavo volumes and took ten days to play, and fifteenth and sixteenth century remains mount up to about two million lines, and through them all there is scarcely any literary work which, as literature, will bear comparison with the twelfth century "Jeu d'Adam." Thus in one further respect mediæval drama follows a law which all French popular literature of the Middle Ages illustrates, epic, lyric and romance—the earliest documents show us the moment of its zenith and all subsequent elaboration seems a gradual decadence.

PROCEEDINGS

OF THE

University of Durham Philosophical Society

(ABSTRACTED FROM THE MINUTES).

November 1st, 1901.

(AT THE COLLEGE OF SCIENCE, DR. MERZ IN THE CHAIR.)

The following Candidates were elected Members of the Society :—

REV. M. BRACK, B.A.
C. H BRYANT, M.D
G W. RICHARDSON, M.D.
H W COUSINS.
F. E W. MASON.
A. MERRICK.
W. SMITH.
W. C SMITH.
A. E TATE.

The Treasurer read his report, which showed the financial position of the Society to be satisfactory, there being a balance of £24 8s. 11d. in hand.

It was resolved that a member should be appointed to edit the Society's *Proceedings* and to report its meetings.

The following officers were elected for the session 1900-1901 :—

President :
THE VERY REV. THE WARDEN.

Vice-Presidents :
PROFESSOR P. PHILLIPS BEDSON, M.A., D.Sc.
REV. H. B. TRISTRAM, M.A., D.D., F.R.S.
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[PROFESS]OR GEORGE R. MURRAY, M.A., M.D.
J. T. MERTZ, PH.D., D.C.L.
S. H. COLLINS.
H. W. COUSINS, A.Sc.

Professor Sampson read a paper on 'The University Observatory.'

November 26th, 1900.

CHEMICAL AND PHYSICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR STROUD IN THE CHAIR.)

The following candidate was elected a member of the Society:—

J. M. BADCOCK.

Dr. Smythe read a paper on 'Some Organic Sulphur Compounds,' giving an account of some unsuccessful attempts to prepare optically active compounds of sulphur.

December 14th, 1900.

BIOLOGICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR LEBOUR IN THE CHAIR.)

Professor Potter gave an account of 'Some recent researches in Plant Nutrition.'

Mr. Collins read a note on 'Molassein.'

January 31st, 1901.

(AT THE COLLEGE OF SCIENCE, DR. MERZ IN THE CHAIR.

Mr. H. E. Watt having resigned the Secretaryship of the

'Chemical and Physical Section,' Mr. T. Baker was elected to fill the vacancy.

Dr. Jevons read a paper on 'Physiological Psychology.'

February 21st, 1901.

BIOLOGICAL SECTION.

(AT THE COLLEGE OF MEDICINE, SIR GEORGE PHILIPSON IN THE CHAIR.)

Dr. Turner read a paper on 'The Liability of Vestigial Structures to Disease, as illustrated by the Vermiform Appendix' and exhibited a series of specimens and preparations.

Dr. Bolam exhibited some new recording instruments for the Physiological Laboratory.

March 7th, 1901.

CHEMICAL AND PHYSICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR STROUD IN THE CHAIR.)

Mr. Patterson gave an account of 'The Principles of Colour Photography,' illustrated by photographs and experiments.

March 14th, 1901.

BIOLOGICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR LEBOUR IN THE CHAIR.)

Dr. Brady read a paper on 'Passages in the lives of some Crustaceans,' dealing more particularly with the structural differences between shallow water and deep sea forms.

Dr. Bedson contributed a note on 'A Deposit of Sulphur in a Colliery Water,' which had been examined by Mr. Stanley.

May 23rd, 1901.

(AT UNIVERSITY COLLEGE, DR. PLUMMER IN THE CHAIR.)

Mr. Urwick read a paper on 'Mediæval Drama in France before the Fourteenth Century.'

LIST OF MEMBERS OF THE SOCIETY.

* *Denotes an original member.*

*Armour, A. L.
Arnison, W. D., M.D.
*Ashton, A. W., B.Sc.
*Baker, T., B.Sc.
Badcock, J. M.
*Bedson, Professor P. P., M.A., D.Sc. (*Vice-President*).
Betts, R. F., B.Sc.
*Bolam, R. A., M.D. (*Vice-President*).
Brack, Rev. M.
*Brady, Professor G. S., M.D., LL.D., D.Sc., F.R.S.
*Brown, G. M., B.A., B.Sc.
Bryant, C. H. M. D.
*Bullerwell, J. W., M.Sc.
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*Cairns, Mrs. C. W., B.Sc.
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*Chaplin, G. P., B.Sc.
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Dudley, C. R.
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Fletcher, Rev. Mark, M.A.
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*Garrett, F. C., M.Sc.
*Gravell, John.
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Howson, C.
Hunter, T.
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*Jevons, F. B., M A., D.Litt.
*Kitchin, The Very Rev Dean, M.A, D D, (*President*).
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Laws, A. R.
*Lebour, Professor, G. A., M.A., M.Sc.
*Linton, A., B.Sc.
Lord, W. Frewen, B.A.
*Louis, Professor Henry, M.A., A.R.S.M.
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Matthews, Miss G.
Maxwell, W. W.

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Merrick, A.
Middleton, Professor T. H.
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Mundella, V. A., M.A., B.Sc.
*Murray, Professor George, M.A., M.D.
*Patterson, R. J., M.Sc.
Pearce, Rev R. J., M.A., D.D.
*Peacock, Miss M. I.
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Proctor, A. H.
*Redmayne, R. R., M.A.
*Richards, W., A.Sc.
Richardson, G. W., M D.
Ridley, Miss E. L. R. M.
Robson, R.
Rollin, C., B Sc.
*Sampson, Professor R. A., M A., (*Vice-President*).
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Smith, W. C.
Smith, Miss K. A , B.Sc.
Smythe, J A., Ph.D., B.Sc.
*Stockdale, H. F.
*Stroud, Professor Henry, M.A., D.Sc.
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Temperley, Miss G.
Thomson, W., M.A.
Thornton, W. M., M.Sc
* Todd, J. J.
Treble, R. L., B.Sc.
Tristram, Rev. Canon, D.D., F.R.S. (*Vice-President*).
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*Urwick, W. E., M.A.
*Wade, Thomas.
Wakerley, F.
Watt, H. E., B.Sc.
Watson, J., B.Sc.
*Watson, F. B., M.A., M.Sc.
Welford, R., M.A.
Wilcox, F A , B.Sc.
Woollacott, David, M Sc.
Woolf, J.
Wright, Professor Mark R., M.A.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

Income and Expenditure Account. Session 1900-1901.

Income.	£	s.	d.	Expenditure.	£	s.	d.
To Balance from Session 1899-1900	24	8	11	By Printing and Issuing Notices of Meetings, etc.	7	12	6
,, 3 Subscriptions for Session 1898-1899 ..	0	15	0	,, Printing *Proceedings*	17	6	0
,, 7 ,, ,, ,, 1899-1900	1	15	0	,, Expenses of holding Meetings ..	2	13	6
,, 81 ,, ,, ,, 1900-1901 ..	20	5	0	,, Secretarial Expenses	1	12	4½
,, Author's Reprints	0	11	6	,, Binding Vol. I. of *Proceedings*	0	2	6
,, Sale of *Proceedings*	0	3	0	,, Assistant Treasurer's Commission	0	12	9
				,, Balance in Treasurer's Hands	17	18	9¼
	£47	18	5		£47	18	5

Examined and found correct.

October 14th, 1901.

HENRY LOUIS, *Auditor.*

FIG. 1.

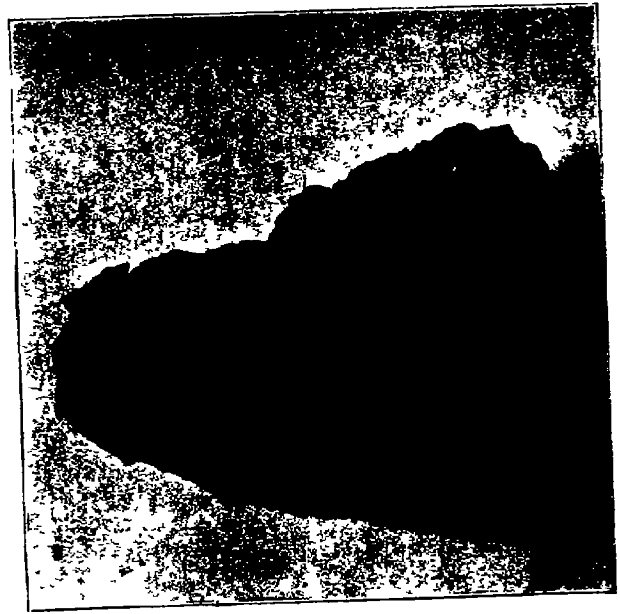


FIG. 2.

On a Canker of the Oak.

(Quercus robur.)

By Professor M. C. Potter, M.A., F.L.S..

[Read December 6th, 1901.]

[The Society is indebted to the English Arboricultural Society for the use of the blocks illustrating this paper.]

Perhaps the best known of the tree-cankers are those of the Larch, Ash and Apple, that of the first-named being especially destructive; but the disease is also of frequent occurrence on other trees.

Generally speaking, a canker arises from the local destruction of the cambium year by year through the action of a parasitic fungus, which is dormant during the summer and resumes an active condition in the winter. Where the cambium is destroyed, no formation of wood and bast can take place; and during the activity of the cambium, from early spring until late summer, an incomplete ring of wood is formed, partially growing over the injury with intent to heal it. Before the next season, however, the activity of the parasite is renewed, and the cambium around the cankered spot is once more destroyed, so that again only an incomplete ring of wood is formed. In this manner the activity of the fungus, alternating with that of the tree, defeats in each succeeding winter the attempts to repair the injury, and eventually a gaping wound is formed which never heals.

In the North of England, cankered Oaks are by no means uncommon. I have found them frequently on trees growing in shady and damp situations, such as the various Denes characteristic of this district, for instance: Deepdale, near Barnard Castle, Bothal, Plessey, Whittle-dene, and various woods on the banks of the Tyne.

A characteristic cankered Oak from Riding-Mill-on-Tyne is shown in Fig. 1. A great cavity can be observed

on one side of the tree, and a conspicuous bulging out of the trunk on either side of it, due to the lateral extensions at the edges of the canker, caused by repeated attempts at occlusion. In the centre of the cavity a dead branch may be seen projecting from amidst the dead tissues. A transverse section taken in the plane of the saw-cut in Fig. 1 is shown in Fig. 2. The last complete ring of wood passes close to the base of the dead branch, where the canker-fungus entered. The tree would then be about twelve years old. It can be plainly seen that after this time no complete rings of wood were formed, and how the attempts to occlude the wound have caused the lateral expansions. The decay has gradually extended to the pith and along the edges of the wound. The sections taken above and below the canker showed the decay spreading in both directions along the centre of the tree. When cut down the tree appeared to be some thirty years old.

These cankers occur at various heights on the stem, from 4 to 20 feet or more. On examination of many specimens attacked in this way, I have almost invariably found numerous fructifications of a fungus belonging to the genus *Stereum* on and around the cankered spot.

No description of a canker caused by any species of *Stereum* having been recorded, the question arose whether this fungus was the cause of the canker or merely a saprophyte living upon the dead tissue. This I sought to determine by endeavouring to produce the disease by artificial inoculations from pure cultivations of the fungus, and after experiments extending over four years I have in this been entirely successful, and have definitely proved the parasitic action of the *Stereum*.

Fig. 3 represents a section through the fungus; the outer surface is composed of a series of club-shaped parallel cells (the *basidia*) forming the hymenium. Some of these project slightly and bear spores, generally four, at the extremity of spike-like projections; others, which do not bear spores, continue their growth and form the hymenium in the succeeding year.

The *Stereum* produces numerous spores during the winter months. Those employed in the experimental cultures were obtained on January 7th, 1899, from a cankered Oak growing in Gosforth Park, near Newcastle-upon-Tyne.

By placing a portion of the fungus face downwards in a sterile, covered glass-dish (petri capsule), I collected the spores as they ripened and fell off, free from the admixture

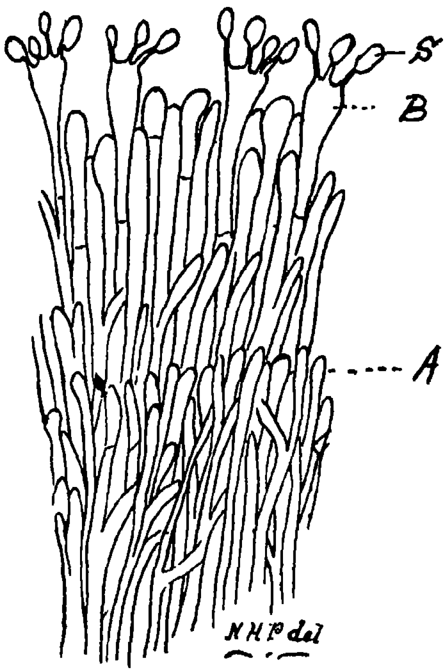


FIG. 3 —PORTION OF HYMENIUM OF *Stereum*.
A—Hymenium of previous year. *B*—Basidium. *S*—Spore.

of spores of other fungi. These spores were sown on January 8th, 1899, by means of a sterile camel-hair pencil, upon sterile blocks of Oak, in a number of large test-tubes plugged with cotton-wool. In a short time the spores had germinated, and the blocks of Oak became covered with a mycelium, eventually producing the *Stereum* form. The germination of the spores was also observed upon nutrient gelatin.

A number of seedling Oaks (3-4 years old), grown in the College garden, were first used for experiment, and numerous attempts were made to induce a canker upon them, but without result. Spores were sown upon the dead twigs, and pieces of Oak, permeated with *Stereum* from the pure cultures, were inserted like buds upon the stems. The conditions, however, were apparently unfavourable to the growth of the fungus. This was not surprising in the vicinity of a large town, where the atmosphere is charged with impurities, and the situation very dry and wind-swept. An attempt was therefore made to infect the young branches of Oaks growing under natural conditions in a wood, and this time with complete success. The trees selected were growing near the bank of a small stream. In many of the young branches, tangential cuts were made of about an inch in length, sufficiently deep to expose the wood, and a small splinter of Oak permeated with a pure culture of the *Stereum* was then inserted in the cut and firmly bound in. Exposure in this way naturally submitted the cultures to the risk of contamination, but under the circumstances this could hardly be avoided.

These out-door cultures were made in November, 1899, this season of the year being favourable for the growth of the fungus. Some of the inoculated branches were cut off at intervals, and brought to the laboratory for microscopic examination, and a series of observations were made at different stages of development.

The first examination, made in May, 1900, after a period of six months, showed that numerous hyphæ of the *Stereum* had grown from the inserted piece of Oak into the living tissues of the branch. The hyphæ, rich in protoplasm, could be seen passing across the lumen of the wood-vessels, both in the neighbourhood of the cut and near the pith; hyphæ could also be observed in the cortical cells at the edges of the incision. The amount of discolouration of the woody tissues was small, and confined chiefly to the medullary rays. There was no indication at this time of any activity on the part of the cambium.

Succeeding periodic examinations enabled me to trace the further development as described below.

During the summer an incomplete ring of wood was formed, together with a callus projecting over the edges of the wound. Meanwhile the *Stereum* remained dormant. On the approach of winter the *Stereum* resumed its active condition, penetrated deeper into the living tissues, as indicated by the brown discolouration, and growing especially at the edges of the incision, extended into and killed some of the cells of the callus. In a section cut from a specimen on the 11th of February, 1901, the discolora-

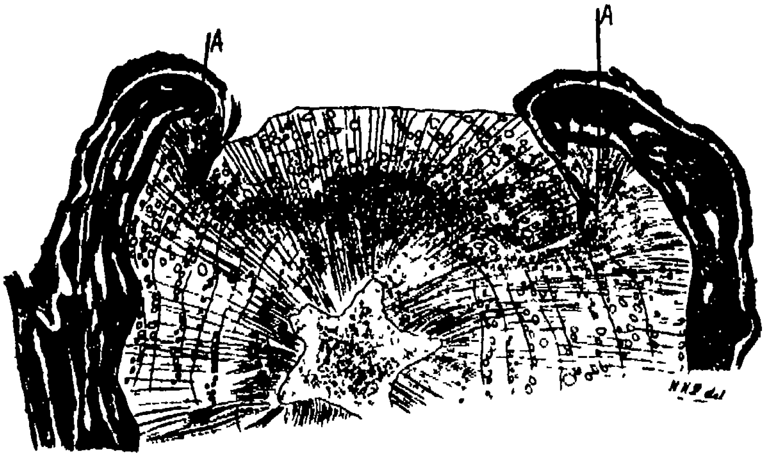


FIG. 4. SECTION OF YOUNG CANKERED OAK.

The dotted shading indicates the region of discoloration due to the action of the *Stereum*. The parasite is seen to be penetrating the callus at *A*.

tion was very pronounced, and extended in a broad zone from the edges of the incision deep into the wood and along the cambium line, being also particularly noticeable along the medullary rays. The callus covering the edges of the incision, formed a prominent feature of the transverse section, and this, too, was locally discoloured. The cells of the callus next the wood were brown and dead, and were no longer in close contact with it. Hyphæ were especially

numerous in the wood-vessels, and were also found in the wood-vessels of the callus. Fig. 4 represents a section cut on September 17th, 1901. The dotted shading indicates the region of discolouration following the penetration of the *Stereum*.

The branches selected for inoculation were small, about half-an-inch in diameter, and showing some five to ten annual rings On these, as we have seen, a miniature canker was produced from a pure culture of the *Stereum*. A continuation of the same process for a number of years would result in the large cankers described on older trees.

No fructifications of the *Stereum* have so far appeared on the artificially produced cankers; but these have only been observed when the canker has reached an advanced stage.

The study of naturally formed cankers indicate their commencement around the insertion of a dead branch. This observation suggested the method employed in my experiments, of cultivating the *Stereum* upon a dead piece of wood before introduction to the living branch. The canker was thus induced from the previous saprophytic growth of the fungus, and it seems highly probable that it first starts as a saprophyte on dead branches, and afterwards attacks the living tissue.

The patches of *Stereum* found on the cankered Oaks are small, irregularly shaped expansions, varying in size from $\frac{3}{16}$ of an inch in diameter, to $\frac{3}{4}$ of an inch long by $\frac{1}{2}$ an inch wide; they are resupinate, coriaceous, and inconspicuous, fitting in between the crevices of the bark to which they are closely applied, and concave, with slightly raised edge. The colour is pale gray to pale brown, corresponding to the *gris clair* and *brun clair* of Constantin and Dufour,* often with a lighter margin. The fructifications do not appear to increase in size after the first year. A number were selected on June 9th, 1898, and needle points driven into the bark at their edges; these were kept under close observation, and after eighteen months showed no enlargement. As the bark decays the fructifications die, and they are only

* "Nouvelle Flore des Champignons," par M. J. Costantin et M. L. Dufour.

found to be living round the edges of the canker. Their life appears to be limited to two, or at most three, years, and usually only two hymenial layers can be distinguished in the older specimens.

The spores are colourless, elliptical with rounded ends, 8·5 $\mu \times 4·3\ \mu$ when measured in water directly they had become detached from the basidia. The basidia themselves are smooth.

In Massee's monograph of the Telephoreæ* there is no description of a *Stereum* which exactly fits the species here described. The species of *Stereum* cited as growing upon the Oak are *St. frustulosum*, *St. disciforme*, *St. spadiceum* and *St. hirsutum*. The three latter belong to a different section of the genus.

In *St. disciforme* the spores, 16 μ in diameter, or 18 $\mu \times 14\ \mu$, are very much larger than those of the canker-*Stereum*, and in other respects it differs greatly.

St. spadiceum has spores 8 $\mu \times 5\ \mu$ the same measurements as those of the canker-*Stereum*, but the character of turning red when bruised found in *St. spadiceum*, together with the reflexed edge, quite distinguish this as a separate species.

St. hirsutum is very common upon felled Oak timber, in which it destroys the sap-wood especially, penetrating the duramen more slowly, and produces a whitish colour in the wood. It in no way resembles the form described here, the ochraceous colour of the hymenium and the form of the fructification at once distinguishing the two species

St. frustulosum Fr. very closely resembles the canker-*Stereum*, but the spores are much smaller, being 4 – 5 $\mu \times 3 – 3·5\ \mu$, with subacute ends. This difference in shape and size of the spores, the cinnamon colour of the hymenium, together with the hair-like projections found on the basidia of *frustulosum*, appear to separate the two species. A more important difference, however, is found in the action of the fungus on the wood. Hartig has

* "Proceedings Linnean Society," vol. xxvii. 1890.

described *St. frustulosum* as causing the appearance technically known as "partridge wood." It attacks the heart-wood, causing it to assume a brown colour with white spots somewhat resembling the feather of a partridge; the white spots eventually become cavities, so that the wood presènts a honey-combed appearance. This parasite, as far as observed, enters the host from the roots, but the possibility of its effecting an entrance through a dead branch is not denied.

The action of the canker-*Stereum* upon the Oak is specially noticeable in the brown discolouration of the medullary rays, both in the artificial cultures and in sections taken from the stem, as in Fig. 2; but the appearance of "partridge wood" is never produced in the cankered Oak. The manner in which the timber is attacked differs markedly from *St. frustulosum*, the smoothness of the basidia also forms a very distinctive feature, and these, taken in conjunction with the characters enumerated above, incline me to consider the canker-*Stereum* a new species, for which I would suggest the name *St. quercinum*.

The Gases Enclosed in Coal and Coal Dust.

By Professor P. Phillips Bedson, M.A., D.Sc.

[Read February 6th, 1902.]

We are chiefly indebted for our knowledge of the nature of the gases enclosed in coal to the investigations of Professor E. von Meyer and those of Mr. J. W. Thomas. The former of these investigators, whilst dealing chiefly with coals derived from German coal-fields, also submitted to examination certain samples of coal obtained from the Durham and Northumberland coal formations. Von Meyer obtained the gases from the coal by placing weighed quantities of the coal in flasks which were filled entirely with water from which the air had been previously expelled by boiling, closing the flasks with stoppers carrying a delivery tube also filled with water. By raising the water in the flask to boiling the gases were liberated from the coal and these were collected and analysed. J. W Thomas adopted a somewhat different method, weighed amounts of coal were placed in glass tubes sealed off at one end and then attached to a Sprengel air pump, by means of which the air was completely removed from the apparatus and in the vacuum thus established the coal was heated by placing the tubes in a water bath maintained at boiling, the gases drawn off and collected over mercury.

The analysis of the gases obtained by these methods demonstrated considerable variation in the volume of gas obtained from equal weights of different coals, and showed also that these gases consist of mixtures of carbon dioxide, oxygen, nitrogen, and marsh-gas; occasionally von Meyer has been enabled to recognise, in addition to these, carbon monoxide, and ethylene, and some higher members of the paraffin series of hydrocarbons, of which marsh-gas is the first member. The following table contains results taken from the works of Von Meyer and of Thomas, and may serve

to give some indication of the nature of the gases enclosed in coal

Name of Seam, etc	Cubic centim'tres from 100 grams of coal.	In 100 Volumes of Gas.			
		Carbon Dioxide	Oxygen.	Nitrogen	Marsh Gas.
Five-Quarter Seam, Wingate Grange, 74 fathoms from the surface	91·2	0·34	trace	13·86	85 80
Low Main Seam, Wingate Grange, 108 fathoms from the surface	238·0	1·15	0·19	14·62	84·04
"Upper 4-Feet Vein," Navigation Colliery, Aberdare District, 400 yards deep (steam)	250 1	13·21	0·49	4·66	81·64
"Upper 4-Feet Vein," Ayfartha Colliery, Merthyr District, 180 yards deep (steam coal)	147·4	18·9	1·02	12·61	67·47

When some years ago Mr. Hall, of Haswell, drew my attention to the easy inflammability of a coal dust formed in screening coal from the Hutton seam at Ryhope, the existence of gases enclosed in the particles of the coal suggested itself as a possible explanation of this ready ignition of the coal dust on the lamps on the screens. This suggestion was submitted to the test of experiment and for this purpose the method adopted by Thomas was, with slight modification, employed. Weighed quantities of dust direct from the screens were introduced into bottles, which were closed by rubber stoppers which carried a bent glass tube for attachment to a mercury air pump of the Geissler type, the portion of the rubber stopper projecting above the bottle neck was carefully covered with a wax cement, so as to make it perfectly gas tight. After exhausting the vessel containing the coal dust, it was heated for several hours in a water bath and the gases so expelled were drawn off into the pump, collected in measuring vessels and analysed. The results of this investigation were communicated to the North of England Institute of Mining and Mechanical Engineers and

published in the *Transactions* in 1888. These experiments demonstrated the existence in the coal dust of gases somewhat similar in character to those obtained by von Meyer and Thomas from certain coals, the volume of gas obtainable from 100 grammes of coal dust when heated *in vacuo* at 100° Cent. varying from 36·5 cubic centimetres and 66·3 cubic centimetres at 0° Cent. and 760 millimetres.

The gases were found to consist of mixtures of carbon dioxide, oxygen, nitrogen, probably some carbon monoxide and of combustible gases, some of which were absorbed by sulphuric acid, consisting possibly of olefiant gas, and also gaseous paraffin hydrocarbons; the latter consisting apparently of mixtures of higher homologues of marsh-gas. The nature of these combustible gases it is, which forms the special interest of the result of this investigation, and although the methods of analysis do not warrant a decision as to the identity of the hydrocarbons entering into the composition of the mixture, still the evidence is sufficient to show that we are not dealing alone, if at all, with marsh-gas, the normal constituent of fire-damp, but with higher members of the same series. This conclusion is of importance as a smaller proportion of such gases would be needed to form an explosive mixture with air, and further, such mixtures would have a lower temperature of inflammation than those of marsh-gas and air. These results, therefore, appeared to provide a satisfactory explanation of the inflammable character of the coal dust in question

Shortly after the completion of this work the College was transferred to its new buildings, and I determined to submit the problem to a re-examination, using for the purpose more refined methods of analysis than it was possible to employ in the cramped conditions and limited accommodation afforded in the premises previously occupied by the College. An account of this second investigation was published in a paper read before the North of England Institute of Mining and Mechanical Engineers in February, 1894, and the conclusions arrived at are confirmatory of these contained in the first publication.

As the researches of von Meyer and of Thomas have shown marsh-gas to be the chief combustible constituent of the gases enclosed in coal, it appeared natural to conclude that the coal from which the dust was produced would also contain this gas, and that its absence from the gases enclosed in the dust is due to its low density and consequent ready liberation from the coal in the finely divided condition of dust. The absence of marsh-gas contributed very materially to the easy recognition of the presence of higher members of the series, for the methods of analysis of such a mixture of hydrocarbons, so similar in composition, give results which afford no definite clue as to the nature of the individuals forming a mixture of this kind, consequently there is always an element of uncertainty in the interpretation of the results The larger the proportion of marsh-gas the less able is one to decide as to the amount of another member of the series present, and the more guarded one must be in interpreting the results of analysis, less errors of experimental determination figure, as a result of calculation, in a proportion of a hydrocarbon other than methane, *i.e.*, marsh-gas. In this instance the results leave no doubt as to the existence of higher members of the paraffin series in the mixed gases, the presence of marsh-gas being alone problematical.

In the second investigation it was attempted to effect a separation of the hydrocarbons by heating the coal *in vacuo* at different temperatures, ranging from 30° to 100° Cent. The results of analysis of the gases extracted at different temperatures indicate such a separation to take place and that the denser gases are retained more firmly by the coal substances than the lighter ones Thus if we represent the hydrocarbons of the marsh-gas series by a formula $C_n H_{2n+2}$, where n is a whole number and for marsh-gas one, the analytical results obtained from the combustion of the gases extracted at different temperatures give values for n varying from 2·1 to 2·8, indicating the gases to be mixtures, possibly of ethane C_2H_6 and propane C_3H_8, the proportion of the latter being greatest in the gases expelled at the highest temperature, viz. 100° Cent.

At my suggestion the late Mr. W. McConnell, jun., A.Sc., undertook, whilst holding the 1851 Royal Exhibition Scholarship, the further study of this question of the gases enclosed in coal and coal dust, restricting the investigation to coal, etc., derived from the Durham and Northumberland coal-fields. An account of the results of this investigation, which extended over two years, is given in a paper read before the North of England Institute in February, 1894.

The validity of the explanation given above of the origin of the gases contained in the coal dust from the Hutton seam of the Ryhope colliery was tested by McConnell, by the examination of the coal itself and the enclosed gases he obtained from it when heated *in vacuo* at 100° proved to contain combustible constituents consisting chiefly of marsh-gas. Further, after the enclosed gases had been removed in this way, the coal was crushed and again heated *in vacuo* at 100°, and was found to yield a further quantity of gas, the combustible constituents of which resembled in composition those obtained from the dust produced in screening the coal. Samples of coal and coal dust from the Hutton seam in two other collieries in the county of Durham and one from the Low Main seam in the county of Northumberland, gave results similar to those obtained with the coal and coal dust from Ryhope. Some other coals and coal dusts examined by McConnell were found to contain enclosed gases entirely free from combustible gases, and to consist mainly of carbon dioxide and nitrogen.

The following results illustrate the differences between the two classes of coal and coal dusts:—

I.—100 grammes of coal give *in vacuo* at 100°, 117 cubic centimetres of gas composed as follows:—

	Volumes.
Carbon dioxide	1·5
Oxygen	1·1
Paraffins (C_nH_{2n+2})	78·0
Nitrogen (N_2)	19·3
	99·9

The paraffins are evidently a mixture of marsh-gas and ethane.

The dust from screening this coal yielded 31·6 cubic centimetres of gas per 100 grammes, the composition of the gas being the following:—

	Volumes.
Carbon dioxide (CO_2) ..	13·08
Oxygen (O_2) . .	0·86
Paraffins (C_nH_{2n+2})	35·65
Nitrogen (N_2) . . .	50·44
	100·00

II.—100 grammes of coal gave *in vacuo* at 100°, 29 cubic centimetres of gas of the following composition:—

	Volumes.
Carbon dioxide (CO_2) .	16·4
Oxygen (O_2) .	3·2
Paraffins (C_nH_{2n+2}) ..	—
Nitrogen (N_2) ..	80·4
	100·0

The dust from screening this coal yielded 42·21 cubic centimetres of gas per 100 grammes, the analysis of which gave the following results:—

	Volumes.
Carbon dioxide	10·26
Oxygen . .	8·03
Paraffins	—
Nitrogen	82·20
	100·49

The inflammation of the coal dust observed occasionally on the screens at Ryhope lends support to the view that this ready ignition, or sensitiveness of the dust is to some extent attributable to the nature of the enclosed gases; a conclusion to which the Austrian Fire-damp Commission arrived from the examination of the gases enclosed in certain kinds of coal dust obtained from Austrian coal-fields.

In his investigation McConnell attempted to obtain a further insight into the nature of the combustible gases gases enclosed in coal by extracting the gases from the coal in fractions. First removing those gases expelled from the coal when heated *in vacuo* at 100°, and then when it had

ceased to yield gas at this temperature, the coal was heated to 130°, when a second fraction of gas was produced, after the removal of which a third fraction was procured by heating the coal to a still higher temperature, viz., 180°. The coal selected for these experiments was that from the Hutton seam at Ryhope, a weighed quantity of which was placed in a tube closed at one end and sealed on to an air pump. This tube was surrounded by another, forming a jacket through which the vapours from boiling water, amyl alcohol and aniline were passed in turn to heat the coal to the desired temperatures. The analyses of the gases obtained in this manner show the possibility of effecting a partial separation of the combustible gases from one another, by reason of the differences in their rates of effusion, which are dependent on their densities. Thus, whilst the greater portion of the enclosed gases is liberated at 100°, the fractions obtained at the higher temperatures, although small in volume, contain combustible gases representing mixtures of paraffin other than marsh-gas.

In consequence of a criticism made by Dr. Broockmann in *Gluckauf* in 1899, I determined to submit this question to a further investigation, but shortly after the commencement of this work Mr. McConnell was accidentally drowned whilst boating off the coast of Northumberland, so that I have lost his friendly assistance in this work. My observations, which were embodied in a paper read before the North of England Institute of Mining and Mechanical Engineers in August, 1902, have in the main confirmed the conclusion stated above. The results of these experiments may be epitomised as follows:—

No. of Experiment	Weight of Coal. Grammes	Volume of Gas per 100 grammes of Coal	
		Volume of Gas drawn off at ordinary temperature and at 100° Cent. Cubic centimetres.*	Volume of Gas drawn off at 109° Cent. Cubic centimetres.*
I.	117·0	148	130·00
II.	110·4	108	88·80
III.	129·6	141	44·25
IV.	67·0	198	170·30
V.	70·0	142	119·30

* At 0° Cent. and 760 millimetres of mercury.

No. of Experiment	Duration of Extraction. Ordinary Temperature.	Steam-heating.
I.	5 days	10½ hours
II.	27 days	31 hours.
III.	10 months and 12 days	30 hours
IV.	9 days	15¼ hours
V.	2 days	49½ hours

The composition of the gases, based on the average of the results in experiments III., IV. and V., and the volume of gas as obtained from 100 grammes of coal, is as follows:—

I.—EXTRACTED AT ORDINARY TEMPERATURE AND AT 100° CENT.

	Cubic Centimetres	Volume Per Cent.	Volume. Per Cent.
Total volume	160·90	—	—
Carbon dioxide	7·02	4·36	4·36
Oxygen	4·53	2 81	—
Marsh-gas	114·50	71·17	71·17
Ethane	10·65	6·62	6·62
Nitrogen	24·21	15·05	4·42
Air	—	—	13·44

II.—EXTRACTED AT 100° CENT., AND INCLUDED IN TABLE I.

	Cubic Centimetres.	Volume. Per Cent.	Volume Per Cent.
Total volume	111·53	—	—
Carbon dioxide	5·15	4·62	4·62
Oxygen	0 46	0·41	—
Marsh-gas	89·84	80·60	80·60
Ethane	10·34	9·27	9·27
Nitrogen	5·74	5·10	3·55
Air	—	—	1·96

III.—EXTRACTED AT 130° CENT.

	Cubic Centimetres.	Volume. Per Cent.	Volume Per Cent.
Total volume	39·09	—	—
Carbon dioxide	0·63	1·61	1·61
Oxygen	3·01	7·70	—
Marsh-gas	5·92	15·14	15·14
Ethane	7·51	19·21	19·21
Nitrogen	22·02	56·34	27·19
Air	—	—	36·85

IV.—Extracted at 180° Cent.

	Cubic Centimetres.	Volume. Per Cent.	Volume Per Cent.
Total volume	22·01	—	—
Carbon dioxide	1·19	5·40	5·40
Oxygen	1·22	5·54	—
Marsh-gas	—	—	—
Ethane	7·65	34·76	34·76
Propane	2·91	13·22	13·22
Nitrogen	9·04	41·08	20·12
Air	—	—	26·41

Another point of interest was brought to light in the course of this investigation, viz., the fact that coal, after removal from the mine, not only gives off some of its "enclosed gases," but takes up the gases from the air and the oxygen preferentially to the nitrogen. Thus, whilst freshly-hewn coal placed in a vacuum gave off in the course of a few days gas of the following percentage composition:—

	Volumes
Carbon dioxide (CO_2)	1·65
Oxygen (O_2)	8·79
Marsh-gas (CH_4)	44·80
Nitrogen (N_2)	44·76
	100·00

The gases given off from coal of the same origin, which had been exposed to the air in the laboratory for some months were found to have the following composition:—

	Volumes
Carbon dioxide (CO_2)	1·18
Oxygen (O_2)	23·80
Marsh-gas (CH_4)	3·58
Nitrogen (N_2)	71·44
	100·00

The Absorption of Arsenic by Barley.

By S. H. Collins, F.I.C

[Read March 6th, 1902.]

This investigation was originally designed to observe in what forms and in what way arsenic was absorbed by plants, and what influence, if any, the supply of phosphates had on this absorption; but the investigation had to be modified during its course owing to the unexpected occurrence of arsenic in the soil used. Whilst the experiment must, therefore, be considered in some respects a failure, yet many points of interest have occurred worth noting.

A set of six 10-inch pots were used, being manured respectively with (1) Nothing; (2) Arsenious acid; (3) Arsenic acid; (4) Superphosphate; (5) Superphosphate and arsenious acid; (6) Superphosphate and arsenic acid. The arsenic being in all cases equal to 11 lb. of arsenic (As_2O_3) per acre, and the superphosphate equal to 170 lb. of phosphoric acid (P_2O_5) per acre. The pots were planted with tares and barley, the former reaped green and the latter thinned in July; the barley gathered in September and divided into (1) bottom half of straw; (2) top half of straw; (3) ears and chaff; (4) grain. Samples of soil being also taken after the close of the experiment. All were then examined by Reinsch's test, using all the crop and 100 grms. of soil, subliming the arsenic and comparing the crystals so formed with a set of standards which had been prepared from varying amounts of from nothing up to 5 mgrms. of arsenic, treated in exactly the same way as the crop.

The distribution of the arsenic in the plant was found to be as follows:—

In the six cases of green stuff there were four cases without arsenic and two cases with arsenic, viz., 0·4 and

0·5 mgrm. of white arsenic per pot. In the lower half of straw, five cases without and one case with 0·5 mgrm. In the upper half of straw, five cases without and one case with 0·7 mgrm.

In the threshed ears, five cases without and one with 0·7 mgrm. In the barley grain, all the six cases contained arsenic varying from 0·5 to 3 mgrm. of white arsenic per pot. All the six samples of soil contained arsenic (7 to 22 parts per million), there being no particular agreement between the amounts artificially added and actually found.

Averaging all the results, the soil contained 30 lb. of arsenic per acre to the depth of 8 inches, the grain contained 4 oz. per acre, and the rest of the plants 1¼ oz. per acre.

The superphosphate did not appear to have any definite action.

After these experiments were finished, another sample of the College garden soil was examined for arsenic and yielded amounts equal to 50 lbs. of white arsenic per acre (to 8″).

Note on a Small Boulder found in the Later Glacial Deposits in a "Wash-out" near Low Spen, in the Derwent Valley.

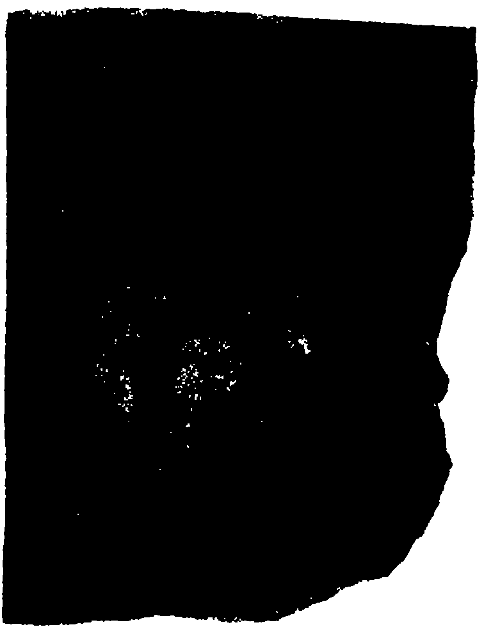
By Professor G. A. Lebour.

[Read May 25th, 1902.]

The specimen exhibited is one which was found by Mr. John Tucker, of Victoria Garesfield Colliery, and handed by him to Dr. Bedson, together with a note giving a very clear and satisfactory account of the circumstances of its occurrence.

The stone, a sub-angular boulder of porphyritic igneous rock, probably of Scottish origin, was found as it is now shown, embedded in a bed of fine, unctuous, highly laminated clay, about 100 feet beneath the surface in a pre-glacial valley which occupies the slack between the hill on which Victoria Garesfield stands and Bradley Fell, in the county of Durham, between the Derwent and the Tyne. This pre-glacial valley constitutes a "wash-out" or eroded ravine (eroded in pre-glacial times) in the Coal-measures. It cuts out the Brockwell seam altogether, and it was in driving a level in that seam that the wash-out was discovered and the stone found. If this wash-out be, as is probable, similar to others known in the neighbourhood, the clay referred to in all likelihood overlies Boulder Clay or Till of true glacial age. This clay (which is similar in character to the so-called "leafy clay" lying above the Boulder in many parts of Newcastle, *e.g.*, between the Central Station and the Mining Institute) was, it is thought, deposited after the final melting of the ice-sheet, and consists of washings of the Boulder clay, carried down from the hills and settled in lake-like pools of the valleys which were more or less dammed up below the points at which it

accumulated under perfectly tranquil conditions. It is most unusual for single stones—especially angular stones—to be found in circumstances such as these, and the only explanation of this occurrence which seems at all likely is that they may have been brought down clasped in the roots of trees during the lake-bursts which everywhere marked the close of the Glacial period Stones brought in any other way would show signs of carriage—would be ice-worn, polished or scratched and this one is not—neither is it water-worn. Possibly stones thus situated may not be so rare as one thinks, but it is seldom that they are luckily noticed by observers capable of understanding the interest that attaches to them or of giving so accurate and valuable a statement respecting their exact position and mode of occurrence as Mr. Tucker has done in this interesting instance. This case is well worth a permanent record.



Small Boulder found in the Later Glacial Deposits near Low Spen.

PROCEEDINGS

OF THE

University of Durham Philosophical Society

(ABSTRACTED FROM THE MINUTES).

November 8th, 1901.

(AT THE COLLEGE OF SCIENCE, PROFESSOR BEDSON IN THE CHAIR.)

Messrs. H Cullen and R. P. Hepple were elected Members of the Society.

On the motion of Professor Louis, seconded by Mr. Collins, it was resolved 'that Life Members be admitted to the Society; and that the Committee be authorised to decide the amount of the life subscription.'

The Secretary of the Geological Photographs Committee reported that during the year Mr. D. A. Woolacott had supplied the following photographs :—

Local Number	
18	Parson's Rock, Sunderland (Cannon Ball Concretions).
19	Holey Rock, Sunderland (Caverns in Magnesian Limestone).
20	Hendon Banks (Exposure of Boulder Clay).
21	Fulwell Quarries (Concretionary structure in Magnesian Limestone)
22	Fulwell Quarries (Raised beach).
23	Fulwell Quarries (Raised beach).

and that copies of these had been forwarded to the British Association's Committee.

The following gentlemen were elected members of the Geological Photographs Committee, with power to add to their number :—Professor Lebour, Professor Louis, Mr Woolacott (Secretary).

Officers for the year were elected as follows :—

President :

THE VERY REV. THE WARDEN.

Vice-Presidents :

R. A. BOLAM, M.D.
PROFESSOR G. A. LEBOUR, M.A., M.Sc.
J. T. MERZ, Ph.D.
A. S. PERCIVAL, M.A., M.D.
PROFESSOR SAMPSON, M.A.
PROFESSOR STROUD, M.A., D.Sc.

Hon. Secretaries :

G. MACK (Coll. Med.).
R. B. GREIG (Coll. Sc.).

Editor of Transactions :

F. C. GARRETT, M.Sc. (Coll. Sc.).

Chairman of the Chemical and Physical Section :

PROFESSOR P. PHILLIPS BEDSON, M.A., D.Sc.

Honorary Secretary :

H. W. COUSINS, B.Sc.

Chairman of the Biological Section :

PROFESSOR GEORGE R. MURRAY, M.A., M.D.

Honorary Secretary :

M. BRACK, B.A.

Committee :

PROFESSOR M. C. POTTER, M.A.
PROFESSOR H. LOUIS, M.A.
S. H. COLLINS, F.I.C.
A. MEEK, M.Sc.
W. M. THORNTON, M.Sc.
A. MERRICK, A.Sc.

Mr. W. F. Lord read a paper on 'The French Conquest of Algiers,' and contended that the position which is occupied by the French conquest of Algiers is this :—that it was the first organised attempt to break up the great Mahommedan empire in North Africa. It was entered upon only three months after the signature of the treaty of London, by which European powers agreed to abstain from further territorial acquisitions at the expense of the Ottoman empire. It was undertaken with the secret assent of Russia and in spite of marked and even angry remonstrance on the part of England. Designed as it was with the two-fold object of adding a profitable colony to the empire of France, and increasing the glory of the Bourbon dynasty, it failed in both directions. The throne of Charles X.

fell ten days after the cannon announced the fall of Algiers; and the province of Algeria has not paid its expenses. It was preceded by elaborate protests on the part of the French Cabinet. M. de Polignac undertook, for his colleagues and himself, that the action of France should be entirely "disinterested," and that nothing should be settled as to the future government of the country without consulting the Sultan. In spite of which the country was annexed and the Sublime Porte was ignored. The threats of England were probably disregarded by the government of Charles X. as they were aware that an internal revolution was impending in England, at the same time that a demise of the Crown might be anticipated.

November 21st, 1901.

CHEMICAL AND PHYSICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR BEDSON IN THE CHAIR.)

Mr. Garrett gave an account of the 'Manufacture of Paraffin from Shale at Broxburn,' and exhibited a number of specimens which had been presented by the Broxburn Oil Co., Ltd.

Mr. S. W. Bell described the geological structure of the Broxburn district, and Mr Philipson, Mr Collis and the Chairman also joined in the discussion.

Dr. Smythe gave an account of some recent research in Organic Chemistry.

December 6th, 1901.

BIOLOGICAL SECTION.

(AT THE COLLEGE OF MEDICINE, PROFESSOR MURRAY IN THE CHAIR.)

Messrs. R. W. W. Bainbridge, G. A. Gilchrist and C. J. H. Stock were elected members of the Society.

Professor Potter read 'A Note on a Canker of the Oak.'

Mr. Meek exhibited some rare marine zoological specimens.

January 23rd, 1902.

(At the College of Science, Professor Sampson in the Chair.)

On the recommendation of the Committee it was resolved to amend Rule V. by adding—'Persons not qualified for the ordinary membership of the Society may become Associates. Associates shall enjoy all the privileges of Members, except that they shall not be eligible to fill any office, nor shall they be entitled to vote.'

Mr. Welford gave a lecture on 'Newcastle a Hundred Year Ago.'

February 6th, 1902.

Chemical and Physical Section.

(At the College of Science, Professor Bedson in the Chair.)

Messrs. M. Holohan, H. H. Simpson, S. P. Smith and P. Widdas were elected members of the Society.

Mr. Collins exhibited a set of specimens from the Stassfurt Potash beds, and Dr. Merz gave an account of the development of the workings.

Professor Bedson read the first part of a paper on 'The Gases enclosed in Coal.'

March 6th, 1902.

Chemical and Physical Section.

(At the College of Science, Professor Bedson in the Chair.)

Mr. Collins read a note 'On the Absorption of Arsenic by Barley.'

Mr. Shilston read a paper on 'The Form of Pressure and Current Waves in the Electric Current.'

Mr. Collins showed an improved Dead-beat Recording Galvanometer; and a new form of Regnault's Hygrometer.

May 15th, 1902.

(At University College, Dr. Plummer in the Chair.)

The Rev. W. R. Adams and the Rev. W. H. Godwin were elected members, and Mr. E. L. Gill an associate, of the Society.

The Rev. W. H. Godwin gave 'Some Studies in the Abbey Rolls of Durham.'

May 25th, 1902.

CHEMICAL AND PHYSICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR BEDSON IN THE CHAIR.)

Professor Lebour read a note 'On a Small Boulder found in the Later Glacial Deposits in a "Wash-out",' and exhibited the stone.

Dr. Bedson read the second part of a paper on 'The Gases enclosed in Coal.'

LIST OF MEMBERS OF THE SOCIETY.

* *Denotes an original member.*

Adams, W. R., B.A.
*Armour, A. L.
Arnison, W. D , M.D.
*Ashton, A. W., B.Sc.
*Baker, T., B.Sc.
Badcock, J. M.
Bainbridge, R. W. W.
*Bedson, Professor P. P., M.A., D.Sc. (*Chairman, Section A*).
Betts, R. F., B.Sc.
*Bolam, R. A., M.D. (*Vice-President*)
Brack, Rev. M., B.A., B.Sc. (*Secretary, Section B*).
*Brady, Professor G. S., M.D., LL.D., D.Sc., F.R.S.
*Brown, G. M., B.A., B.Sc.
Bryant, C. H., M.D.
*Bullerwell, J. W., M.Sc.
Cadman, J , B.Sc.
*Cairns, Mrs. C. W., B.Sc.
Cairns, C W , M.Sc.
*Campbell, William, B.Sc
Carrick, D R.
*Caunt, G. W., M.A.
*Chaplin, G P., B.Sc
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*Cooper, J , B.Sc.
Cousins, H. W., B.Sc. (*Secretary, Section A*).
Cullen, H. R., B.A.
*Dale, Sir David, Bart , D.C.L., D.L.
Dixon, J. G.
Dow, C. R., B.Sc.
Dudley, C. R., A.Sc.
Dunn, J. T., D.Sc.
HAW, Rev H., M.A.
Elsdon, E. J., A.Sc.
Fletcher, Rev. Mark, M.A.
*Fowler, Rev. J. T , M A., D C L.
*Garrett, F. C., M.Sc. (*Editor*).
Gill, E. Leonard (*Associate Member*).
Gilchrist, G A.
Godwin, Rev. G. H., M.A.
*Gravell, John.
*Gray, W. R. H., M.A.
Greig, R. B. (*Secretary*).
*Gurney, Rev Principal H P., M A., D C L
Hardie, T.
Hatton, R. G.
*Havelock, T. H., M A., M.Sc.
Hayward, J. W , M.Sc.
*Heawood, P J , M A.
Hepple, R. P.
Hodgkin, T. E.
Holohan, M., A.Sc.
*Howden, Professor R., M.A., M.B.
Howson, C., B.Sc
Hunter, T., A.Sc.
*Jessop, Professor C M , M.A.
*Jevons, F. B., M A., D.Litt.
*Kitchin, The Very Rev. Dean, M.A., D D (*President*).
*Knight, R.
Laws, A. R.
*Lebour, Professor G. A., M.A., M.Sc. (*Vice-President*)
*Linton, A., B.Sc
Lord, Professor W. Frewen, M.A.
*Louis, Professor Henry, M.A., A.R.S.M.

Lovibond, J. L., M.A.
Lyle, R. P. Rankin, M.D.
Mack, G. (*Secretary*).
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Mason, F. E. W., B.Sc.
Martin, Miss E. M.
Matthews, Miss G
Maxwell, W W., B.Sc.
*Meek, A., M.Sc.
Mellanby, A. L., M.Sc.
Merrick, A.
Middleton, Prof. T. H., M.Sc.
*Merz, J. T., Ph.D., D.C.L. (*Vice-President*).
Mundella, V. A, M.A., B.Sc.
*Murray, Professor George, M.A., M.D. (*Chairman, Section B*).
*Patterson, R J., M.Sc.
Pearce, Rev. R. J., M.A., D.D.
*Peacock, Miss M. L, A Sc.
*Percival, A. L., M.D. (*Vice-President*)
*Philipson, Professor Sir G. H., M.A., M.D., D.C.L.
Philipson, W., A.Sc.
*Plummer, Rev. A., M.A., D.D.
*Potter, Professor M. C., M.A.
Potts, G., B.Sc., Ph.D.
Proctor, A. H.
*Redmayne, R. R., M.A.
*Richards, W., A.Sc.
Richardson, G. W., M.D.
Ridley, Miss E. L. R. M., A.Sc.
Robson, R., B.Sc.
Rollin, C., B.Sc.
*Sampson, Professor R. A., M.A. (*Vice-President*).
Simpson, H. H., A.Sc.
Smith, W.
Smith, W C., B.Sc.
Smith, S. P.
Smythe, J A., Ph.D., M.Sc.
Stock, C. H. J.
*Stroud, Professor Henry, M.A., D.Sc. (*Vice-President*).
Tate, A. E., B.Sc.
Temperley, Miss, M.A.
Thomson, W., M.A.
Thornton, W. M., D.Sc
*Todd, J. J, A.Sc.
Treble, R. L., B.Sc.
*Tristram, Rev. Canon, D.D., F.R.S.
*Urwick, W. E., M.A.
*Wade, Thomas.
Wakerley, F., B.Sc.
Watt, H. E., M.Sc.
Watson, J., B.Sc.
*Watson, F. B., M.A., M.Sc.
Welford. R., M.A.
Widdas, P
Wilcox, F A., B.Sc.
Woolacott, David, M Sc.
Woolf, S.
Wright, Prof. Mark R., M.A.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

Income and Expenditure Account. Session 1901-1902.

Income.	£	s.	d.
To Balance from Session 1901-1902	17	18	9¼
,, 8 Subscriptions for Session 1900-1901	2	0	0
,, 84 ,, ,, , 1901-1902	21	0	0
,, 5 ,, ,, ,, 1902-1903	1	5	0
,, Author's Reprints	1	11	0
,, Sale of *Proceedings*	0	13	0
	£44	7	9¼

Expenditure.	£	s.	d.
By Printing and Issuing Notices of Meetings, etc.	5	9	11
,, Printing *Proceedings*	15	13	6
,, Expenses of holding Meetings	3	6	0
,, Secretarial Expenses	1	12	11
,, Assistant Treasurer's Commission	0	11	0
,, Balance in Treasurer's Hands.	17	14	5¼
	£44	7	9¼

October 15*th*, 1902.

Examined and found correct.

HENRY LOUIS, *Auditor*.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

MATHEMATICS AS A MEANS AND AS AN END.

By Professor R. A. SAMPSON, M.A., F R.S.

[Read June 20th, 1902.]

Of all the aspects from which mathematics may be regarded that which most appeals to me looks upon it as a branch and a tool of philosophy. The symbols, figures and abstractions under which it handles, or professes to handle, natural objects or quantities are themselves symbols of the larger symbolism which is the essence of all our apprehensions. It is probably true to the very letter that

> Alles Vergangliche
> Ist nur ein Gleichniss.

—"All that is temporal is but a symbol"—that is to say, that all our most concrete ideas—beginning, let us say, with the idea of colour, where the fact is demonstrable—are no more than models or diagrams which keep pace in some arbitrary fashion with realities which we are unable more correctly to describe. From this point of view, just as players are the "abstract and brief chronicle of our time," so mathematics is an abstract and brief chronicle of philosophy.

But mathematics is much more than a general parable of our view of nature. It is far the most promising engine of research, and almost the only fully reliable one, for separating what is necessary from what is accidental, in any analysis of thought and its method; in affording examples in which logic is incapable of furnishing any single solution to a problem, owing to the conditions being themselves

indeterminate; in illustrating what is arbitrary in our connection of cause and effect by showing how our logical steps are in many vital ways a matter of definition; in showing the dangers of argument upon ideas which are ill-defined or which perhaps are impossible to define, by exhibiting the almost endless subtleties to which the full discussion of such simple ideas as those of number lead when investigated thoroughly.

I will illustrate what I mean by a few simple examples. How much labour, what reams of paper and ink have been spent upon the task of defining the Real, of defining apart from one another, two elements of our consciousness, a subjective and an objective, and this in spite of the admitted fact that nothing but hypothesis can draw the line between them Now, if we put such a case to ourselves in mathematical form, it is merely an indeterminate equation, say $x + y = 1$, in which some may prefer the solution $x = 0$, $y = 1$, and some $x = \frac{1}{2}$, $y = \frac{1}{2}$, but there is no justifiable view except that we knew nothing of the parts, and only the same total.

One other illustration of this matter. It is certain, I suppose, that whatever external objects may be, our knowledge of them is fragmentary. We can only watch one thing at a time and meanwhile must carry forward the others in a way that shall fit their appearance when we next encounter them. In what way then do we complete these fragments? Here again the operations of the mind in a simple parallel case can be followed with certainty in the field of mathematics. Take the case of number; here we have in the first instance a discontinuous or fragmentary system, whose gaps it is for other purposes essential to bridge over. How this may be done with security, what alternative ways there are of doing it, and what assumptions are thereby introduced into any particular method, is a study which no one who wishes to walk safely in metaphysic should disregard.

I must not devote too much attention to a special theme, or I could give you many other examples of the way in

which mathematics is making for pure philosophy gauges, tests and rules which, admitting their need for thousands of years, she has never succeeded in constructing herself.

I am well aware that many men, both learned and skilled in mathematics, would inhibit as a poison the applications of which I have spoken My own sympathies by no means consent to that, and besides it is no longer possible to do so. A couple of generations ago there stalked abroad in mathematics several ancient and dangerous paradoxes, which waylaid many ingenious people and drove them clean out of their wits, and frightened many more. These creatures have now, I believe, all been trapped and tamed, but this could not be done without a criticism of the elements But it is easy to spend too much time upon such matters. Dedekind himself appears to admit that life is too short for the discussions that ensue in proving with rigour such a theorem as $\sqrt{2} \times \sqrt{3} = \sqrt{6}$. Very few would learn the power and interest of mathematics were it not for the body of algorithms, varied, fertile and endless, to which one is introduced with the first identity of elementary algebra and the first proposition of Euclid, and which run on in all directions without end. New forms continually arising which simplify and include the old which thus become simpler as they grow more general, and, whether regarded for its results or its methods, produces a mass of detail which is justified apart both from its use and its origin in the spontaneous interest it evokes in every mind that can understand it.

Long life to conic sections! May their shadow never grow less! But I am afraid we are passing into a time when nearly all their details will be considered a luxury for the few. In his own garden, nay, in a single handful of earth, a man may find endless theme for study and wonder; but to-day the world feels like one who is getting on in years and cannot afford the time required. Whether we want mathematics for its own sake or for its uses, we have far to travel, and we cannot afford to examine every flower, leaf and weed that we meet, sure though we may be that they

would repay us. In short there appears to me to be imperative need in the earlier parts of mathematics to simplify, select and reject, so that those who come to it should be able to reach some central vantage ground in the readiest possible way, from which they can afterwards get on further in any direction they think fit.

I will not attempt at the present moment to indicate how I think this might be done. I will only allude to one difficulty. Is the straight road upon which we are to travel rapidly and far in mathematical science to be a mere short cut? Are we to sacrifice exact demonstration, let us say, in the rudiments of the calculus or the theory of ratio and incommensurables, and return to geometrical or other demonstrations which profess to be intuitional, but which involve fallacies or assumptions that are now perfectly well understood? I think it is now impossible to do so, even if it were desirable. Rigour in proof is difficult to attain and frequently very tedious, but to put forward a proof which professes what we know it cannot carry is a mere imposture, and cannot be tolerated. But there is a *via media*. In long proofs it not infrequently happens that a great part of the effort is spent upon recondite exceptions of rare occurrence. It seems to me that once the nature of these is known, the wiser plan is to shut them off from general consideration, devoting attention to framing a statement of sufficient limitations under which we may trust what remains This remark has a wider bearing than might at first be supposed. For example, in old-fashioned books we used to find sundry proofs of the parallelogram of forces, Duchayla's proof, proofs for the direction knowing the magnitude, and so forth. They are so much waste paper. It is now admitted I think that the parallelogram law is essentially part of the definition of a vector, and that if we cannot see that part of the phenomenon of stress may be isolated and identified with the properties we ascribe to a vector, nothing can be done to prove it. Or again, take D'Alenbert's principle. The so-called proofs of this principle amount to no more than hypotheses as to the inter-

actions of infinitely small particles of a body—a matter of which we have no experimental knowledge whatever. It is more proper to assume such a principle plainly, as a definition of the limits of our investigation, than to profess to deduce it, *ignotum per ignotius*, from other matters which have no real relevance to it.

Mathematics at the present day is in a very unfixed state, as is natural when so many are engaged in underpinning its foundations; and the case is complicated by something of a revolt by those who have to use mathematics in practical life against the manner in which it is taught, which they say is pedantic, not adapted for ultimate use, and of doubtful success as a training. In this contest my sympathies are entirely with the user, and I do not doubt he will ultimately carry the body of teachers with him. I am convinced that all valuable ideas may be fully stated and presented from an elementary point of view at a very early stage of study. I will give you only one illustration; the indispensable theory of logarithms. Far the simplest way of presenting logarithms is not by the theory of indices, but by the theory of the association of the elements of two sequences; and the simplest way of calculating them is derived from this and not from the theory of series; and both of these methods were known in the time of the inventor and were in fact the actual method by which the first tables were constructed. "Logarithms," says Briggs, "are numbers which associated with proportionals yield constant differences."

A society like our own should not make its chief aim originality. In the study of mathematics that could only bring failure. Within a much less ambitious sphere there is material that would be interesting and profitable to us all. I would commend to you specially studies intended to simplify or co-ordinate known branches, to present them under some new relation; studies in the history of famous mathematical problems, or a rescention of some sequence of theorems involving a great cardinal idea. It is easy to mention almost any number of such matters which are easily

accessible, and which are well worth telling and retelling. For example: the theorem that every equation has a root; the simple theory of functions of a complex variable; the rudiments of non-commutative algebra; the existence-theorem of the solution of differential equations; applications of invariants; magic squares; historical puzzles and paradoxes; or, in the field of applied mathematics, modern mechanical illustrations of electrical and magnetic phenomena; elementary ideas of thermodynamics; graphical solutions and tests of their exactness; the foundations of the laws of motion; optics and the eye; the theory of vision and its interpretation; and the number might be increased indefinitely.

I will not detain you longer. I will only say, in conclusion, that if anyone feels the power and beauty of mathematics, and will diligently try to apprehend and express in its simplest way the idea that appeals to him, he will be doing a work that will be profitable to himself, and an interest and stimulus to others.

A Note on Selenium.

By M. Holohan, B.Sc..

[Read November 21st, 1902.]

Selenium is an element very closely allied to sulphur, and we find in most specimens of pyrites that part of the sulphur is displaced by this element. In the burners it is oxidised along with the sulphur, and the dioxide formed is again reduced by the sulphur dioxide to elemental selenium, which condenses in the flues, the dust periodically collected from the latter, being the chief source of the element. Some of the selenium penetrates to the chambers and it may be detected in the chamber deposits, as well as in the sulphide of arsenic which is obtained in the purification of sulphuric acid. As the impure acid is used in the Leblanc process, we also find selenium in the deposits at the bottom of the hydrochloric acid cisterns. Selenium is extracted from these various deposits by the oxidation and subsequent reduction of the element.

The common recipe given is to boil up the dust with sulphuric and nitric acids, boiling down the filtered liquid with hydrochloric acid and passing sulphur dioxide through the mixture. But the lack of detail makes this method unsatisfactory, and the results are very poor. What has been found the most profitable method consists in stirring up the dust to a thick paste with strong nitric acid, and heating the paste, until red fumes of oxides of nitrogen cease to be evolved in large quantity. Hydrochloric acid is then added and the heating continued as long as chlorine is evolved; excess of nitric acid is thereby destroyed, and the oxidation completed. The liquid is diluted and filtered, and an equal volume of hydrochloric acid is added to the filtrate, which is then boiled down on the water bath to a quarter the bulk. The liquid is cooled and diluted and sulphur dioxide gas is

passed through it, when selenium is thrown down. It is important that there be no large excess of nitric acid present as it tends to prevent the reduction.

As further safeguards, however, it is advisable to dilute the liquid well and to keep it cool.

The selenium deposited is a brick red powder, which when heated in suspension in water darkens in colour, and flocculates, forming a black spongy mass, both the red and black varieties being different forms of the amorphous modification of selenium.

When either is heated, out of contact of air, it begins to soften a little above 100° C., and melts probably about 180° C. On allowing molten selenium to cool, there is left a black compact vitreous mass which seems to be a transition form between the amorphous and the so-called "metallic" variety. This latter is formed (according to Mitscherlich) when molten selenium is raised to 217° and then cooled to 180°. After being kept for some time at that temperature, it suddenly becomes crystalline with rise of temperature.

On heating selenium in air it burns with a blue flame, similar to that of sulphur, evolving white fumes of the dioxide which have a characteristic odour resembling decaying horseradish. The dioxide may be prepared by burning selenium, but is better obtained by dissolving the element in nitric acid, evaporating to dryness, and subliming the residue, when it is obtained in the form of white needle-shaped crystals, which are *fairly* permanent in air. They are very soluble in water, and on concentrating and cooling the solution, selenious acid crystallises out in colourless prisms, which are very soon coated with a red layer of selenium owing to partial decomposition in air. Selenic acid is obtained by oxidising selenious acid by means of bromine or chlorine. The liquid obtained on being concentrated very much resembles sulphuric acid.

An interesting compound of selenium is the di-sulphide which is readily obtained on passing hydrogen sulphide into a solution containing selenium, as a bright yellow precipitate, which darkens considerably on drying. It is impossible to

obtain it absolutely pure, as it always contains both free selenium and free sulphur. It is soluble in alkaline sulphhydrates, forming an oily and highly refractive solution. Another compound—the di-selenide of sulphur—is obtained on passing seleniuretted hydrogen into a solution of a sulphite or sulphate.

The selenites and selenates, resemble very much the corresponding sulphites and sulphates, except in their instability. And the most marked characteristic of the selenium compounds generally is their instability in air; for this reason it is very difficult to obtain a crystalline selenium compound which has not free selenium mixed with

On the Decomposition of Oxalic Acid by Bacteria.

By Prof M. C. Potter, M.A.

[Abstract of a Paper read January 22nd, 1903.]

It is well known that considerable quantities of oxalic acid are formed in plant tissues, as shown by the numerous crystals of calcium oxalate which are found in leaves, especially the petiole, and also in those parts which are periodically cast off. The researches of Topf* and the author† have also shown that oxalic acid is produced by certain bacteria.

Were there no means of decomposing this calcium oxalate large quantities of carbon hydrogen, oxygen and calcium would be locked up annually and the accumulation of this salt, in the course of time, would be very disastrous.

The author has isolated from the soil an anaërobic schizomycete which is capable of decomposing oxalic acid in solutions of vegetable extracts such as neutral turnip broth, one of the products being CO_2.

In the process of respiration CO_2 is generally the end-product, but this is not always the case, as is shown by the fact that in succulents the end-product of respiration is largely oxalic acid. The suggestion is offered that oxalic acid being one of the products of respiration, when only incomplete oxidation is effected, the schizomycete takes up the respiration at the oxalic acid stage and continues the oxidation until the final end-product of CO_2 is attained.

* Topf, "Oxalsäurebildung durch Bakterien," *Berichte d. deutsch. Bot. Gesellschaft*, Bd. xviii., 1900.

† Potter, "On the Production of Oxalic Acid by Bacteria," *Proceedings of the University of Durham Philosophical Society*, vol. i., pt. iv., 1900. "On a Bacterial Disease of the Turnip (*Brassica napus*)," *Proceedings of the Royal Society*, vol. lxvii., 1901.

The Decomposition of Chlorates

By William H. Sodkau, B Sc., F I.C.

The majority of chlorates have properties differing very markedly from those of potassium chlorate. Calcium chlorate $Ca(ClO_3)_2 2H_2O$ for example, is an extremely deliquescent and readily soluble substance, whilst lead chlorate $Pb(ClO_3)_2 H_2O$ although not deliquescent, dissolves in one third of its weight of cold water. Barium chlorate and silver chlorate are not excessively soluble. The most convenient method for preparing a given chlorate is usually by treating the sulphate of the metal with barium chlorate, but if the sulphate is insoluble in water the carbonate or oxide of the metal should be treated with chloric acid, prepared from barium chlorate and sulphuric acid. The materials should be very carefully purified as it is scarcely practicable to remove impurities from the average chlorate.

The preparation and more obvious properties of many chlorates have been described by Wächter.* Some chlorates are extremely unstable. Manganous chlorate decomposes during the concentration of its solution by evaporation over sulphuric acid, and a clear solution of stannous hydroxide in chloric acid spontaneously exploded.† Silver chlorate may be decomposed in a regular manner if the heat is very carefully controlled, but when a bunsen flame is applied to a test tube containing about a gramme of this substance, and having its mouth partially closed by means of an ordinary one-holed rubber stopper in order to slightly restrain the hot gases, the chlorate fuses, begins to decompose and then (at about 350° C.) suddenly explodes with a yellow flash, the tube being shattered. When treated similarly, barium chlorate gives a rapid rush of gas at about 400° C., the mass

* *J. Pr. Chem.*, 1843, 30, 321.
† Wächter.

becoming red hot. With potassium chlorate it is necessary to raise the temperature well above 500° C. in order to obtain a really rapid evolution of oxygen, the fused chlorate then looking somewhat like a boiling liquid. The decomposition of a chlorate is accompanied by a considerable evolution of heat, which tends to raise the temperature of the mass, thereby increasing the rate of decomposition and consequently the heat production. Were it not for radiation this action would always be progressive and lead to an explosion, but in the case of potassium chlorate (where $2KClO_3 = 2KCl + 3O_2 + 19{,}400$ cal.) the temperature for rapid decomposition is so high that the heat evolution may be balanced by the radiation, provided the area of surface per unit of mass is fairly large, as in the small mass employed in the above experiment. As the mass is increased the relative surface, and consequently the loss by radiation, is decreased. One might therefore expect that if many tons of potassium chlorate were strongly heated, the temperature would rise very rapidly and so bring about an enormous rate of decomposition similar to that so easily obtained with a small quantity of the less stable silver chlorate. This appears to to have been the reason of the disastrous explosion of about 160 tons of potassium chlorate at St. Helen's on the 12th of May, 1899. Quite a small quantity of potassium chlorate will undergo fairly violent decomposition if a high temperature is maintained on all sides of it. Thus a small bead held in a bunsen flame by means of a looped platinum wire decomposes about as violently as does nitroglycerin under similar conditions.

The following account of an investigation of the actual mechanism of the decomposition of chlorates may not appear strictly logical as it has been necessary to omit many details published in the *Transactions* of the Chemical Society.*

Perchlorate Formation and its prevention by addition of Oxides of Manganese.—It has been suggested that the forma-

* Sodeau, "Decomposition of Chlorates," *Trans. Chem. Soc.*, 1900, pages 137-150 (potassium and barium); 1900, pages 717-725 (lead); 1901, pages 247-253 (calcium and silver); 1901, pages 939-943 (supposed "mechanical" facilitation); 1902, pages 1066-1076 (oxides of manganese and perchlorate theory).

tion of potassium perchlorate on heating the chlorate is due to the breaking down of a large chlorate molecule containing perchlorate groups. It is, however, difficult to reconcile this view with the variation of the proportion of perchlorate according to the rapidity of the heating, and with the entire absence of perchlorate when decomposition takes place in presence of hydrochloric acid or of oxides of manganese. Such a view is further complicated by the observation that some potassium chlorate is formed when the perchlorate is heated, and by the fact that other chlorates give very different proportions of perchlorate. Thus, according to Potilitzin, calcium chlorate gives only one molecule of perchlorate to about 17 to 20 of chloride. The formation of potassium perchlorate cannot well be due to the oxidation of the chlorate by free oxygen, for the course of the decomposition does not appear to be affected by reduction of pressure.

Heated potassium chlorate acts as a strong reducing agent towards silver oxide, mercuric oxide, and the peroxides of lead and barium. It seems practically certain that when heated alone it undergoes a self-oxidation and reduction in the sense of the following equation:—

$$KClO_3 + 3KClO_3 = KCl + 3KClO_4 + 61{,}300 \text{ cal.}$$

This reaction doubtless takes place concurrently with the simple decomposition into chloride and oxygen:—

$$2KClO_3 = 2KCl + 3O_2 + 19{,}400 \text{ cal.}$$

These two reactions are probably independent of each other and differently affected by variations of temperature, etc. The numerical results indicate that the first reaction proceeds at from 1·5 to 2·95 times the rate of the second according to the conditions under which decomposition takes place.

In presence of oxides of manganese no perchlorate is formed as the decomposition into chloride and oxygen then takes place at a temperature far below that at which the "perchlorate" reaction proceeds with an appreciable velocity.

The formation of perchlorate during the decomposition of

other chlorates has not received much attention, but the mechanism is probably the same in all cases.

Previous workers have published equations such as $22KClO_3 = 8KCl + 14KClO_4 + 5O_2$ to approximately express their results, but a different equation is required for each set of conditions. If the decompositions of barium chlorate (*vide* next section) were to be expressed by a series of complex equations, terms such as 1,500 $Ba(ClO_3)_2$ would be required. In studying chemistry one meets with many cumbersome equations which convey nothing very definite beyond the proportions found in an analysis of the products. It seems very probable that in these cases, as in the decomposition of chlorates, the absence of any simple molecular ratio between the amounts of the products is due to the simultaneous occurrence of two or more independent reactions. Perhaps some future worker may make these cases more intelligible by determining the nature of the independent reactions and their relative velocities under different conditions.

The Evolution of Oxygen and Chlorine during Decomposition.—In general, one may say that the proportion of free chlorine increases as the base becomes weaker or as the rate of decomposition is increased. Thus when potassium chlorate is slowly decomposed in a platinum vessel, pure oxygen is evolved and the final residue consists of neutral potassium chloride. Magnesium chlorate, on the other hand, decomposes entirely into oxide, chlorine and oxygen when rapidly heated, according to Wächter (*loc. cit.*). In order to ascertain the mechanism of these changes the chlorates of potassium, barium, calcium, lead and silver have been studied. The experiments were conducted under pressures varying from 1 mm. to 1 atmosphere, decomposition being effected in times varying from a fraction of a second to several hours according to the temperature employed. The relative proportions of oxygen, chlorine, oxide, and chloride were ascertained mainly by examination of the residues. To facilitate comparison between different chlorates the total chlorine in any chlorate always put = 100.

Some examples of the results obtained are given in the Table, p. 116, and their theoretical significance will now be discussed.

Two theories have been published by previous authors to explain why the proportion of chlorine liberated during the decomposition of chlorates by heat, should vary with the nature of the base and the mode of heating. H. Schulze* supposed the chlorate to decompose entirely into chloride and oxygen, the chlorine resulting from the action of "nascent oxygen" upon the chloride. W. Spring and Prost† on the contrary suggested that the chlorate decomposed entirely into oxide and Cl_2O_5, the latter immediately breaking up into chlorine and oxygen, and more or less of the chlorine then reacting with the oxide to form chloride with liberation of more oxygen.

It will be noticed that these explanations are in direct opposition, but in neither of the papers does there appear to be evidence that the suggested second action actually takes place under the conditions obtaining in the decomposition, nor does either deal with possible alternatives, of which there would seem to be two, namely, (1) the simultaneous formation of both oxide and chloride as *direct* products, and (2) the simultaneous action of chlorine and oxygen upon the residue first produced.

For the purpose of discussion, it is convenient to classify the different reactions which might give rise to the formation of oxide and chloride (evolution of chlorine and oxygen) during a decomposition.

(*a*) Chlorate giving chloride and oxygen.

(*b*) Chlorate giving oxide, chlorine, and oxygen.

(*c*) Chlorate acting upon chloride with liberation of chlorine.

(*d*) Oxygen and chloride giving chlorine and oxide, apart from reverse action (*e*).

(*e*) Chlorine and oxide giving oxygen and chloride, apart from reverse action (*d*).

* *J. Pr. Chem.*, 1880, ii., 21, 407.

† *Bull. Soc. Chim.*, 1889, iii., 1, 340.

(*f*) Simultaneous action of oxygen and chlorine, as in (*d*) and (*e*) combined.

Barium Chlorate and Calcium Chlorate (see Table, p. 116). —According to Spring and Prost the whole of the chloride in the residues is formed by the action of chlorine on the oxide of the metal. This action is evidently not complete under atmospheric pressure and, in accordance with the law of "mass action," would be much less so when the concentration of the gas had been reduced by expansion, consequently very much less chloride and a large amount of free chlorine should have been produced in decompositions under reduced pressure.* The proportions of chloride (99·934 and 99·46 per cent. respectively) produced at the low pressure were not, however, less than those obtained under atmospheric pressure, hence reaction (*e*) cannot take place to any appreciable extent and the views of Spring and Prost are incorrect. It was also found that no chlorine was displaced from the chlorides of barium and calcium by the action of the corresponding chlorate during its decomposition, hence reactions (*c*) (*d*) and (*f*) do not occur to any appreciable extent; this excludes Schulze's theory. Schulze obtained traces of chlorine on heating barium chloride with potassium chlorate but it was found that this experiment was really a decomposition of the barium chlorate formed by double decomposition and had therefore been wrongly interpreted. From this process of exclusion it appears that, in addition to the formation of perchlorate, reactions (*a*) and (*b*) are the only ones which occur. In the case of barium chlorate these are

(*a*) $2Ba(ClO_3)_2 = 2BaCl_2 + 6O_2 + 43{,}800$ cal.

(*b*) $2Ba(ClO_3)_2 = 2BaO + 2Cl_2 + 5O_2 - 97{,}200$ cal.

In slow decompositions the velocity of (*a*) is about 1,000 to 1,500 times that of (*b*), but at a higher temperature when the decomposition is rapid, being completed in about half a minute, the ratio is only 140 : 1, this being presumably an example of the tendency of endothermic reactions to relatively gain at higher temperatures.

* For experimental confirmation of this see below under lead chlorate and silver chlorate.

With calcium chlorate the ratios are about 180 : 1 and 45 : 1 respectively. The decomposition of barium chlorate was retarded by addition of barium chloride and markedly facilitated by reduction of pressure (removal of oxygen). This would almost seem to indicate the existence of some inverse action.

Neither addition of potassium chloride nor reduction of pressure to 1 mm. had any marked effect upon the rate of decomposition of potassium chlorate whilst reduction of pressure impeded the decomposition of lead chlorate—a rather surprising fact.

The results with other chlorates will be briefly summarised.

Potassium Chlorate.—A glance at the Table on p. 116 shows that in this case the only reaction worth considering (in addition to the self-oxidation to perchlorate) is the decomposition into chloride and oxygen, as this proceeds at not less than 50,000 times the rate of any reaction yielding free chlorine.

Lead Chlorate presents a marked contrast to the chlorates described above. For every molecule yielding chloride and oxygen during slow decomposition about seven give peroxide, chlorine and oxygen, but the liberated chlorine at once begins to act on the lead peroxide with production of chloride and oxygen. This appears to prove that the lead is directly attached to oxygen in the chlorate.

The effect of varying the pressure may be seen from the Table. By certain methods, described in the original paper, it was ascertained that the liberation of about 87·5 per cent. of the total chlorine was the limit when secondary reactions were eliminated and that about 12·5 per cent. of the total possible chloride was formed directly.

Silver Chlorate gave results even more striking than those just described. It will be seen from the Table that as the pressure was reduced from 760 mm. to 2½ mm. the free chlorine increased from 0·2 to 22·6 per cent. From a consideration of the curve showing the relationship between pressure on the one hand and the ratio of chloride to oxide

on the other, it appears that if the pressure above the fused chlorate were reduced to zero, 36 per cent. of the chlorine would be obtained in the free state. Hence at least 36 per cent. of this chlorate is decomposed directly into oxide, chlorine and oxygen, but under atmospheric pressure practically the whole of the liberated chlorine reacts with the oxide.

A reference to the structural formulæ of chlorates will be found on p. 117.

The Decomposition of Potassium Chlorate in presence of Oxides of Manganese.—The facilitating action of various substances on the decomposition of potassium chlorate has been held by some to be wholly or partially mechanical and has been compared to the action of sand, etc. when thrown into superheated water. That such comparison is misleading should be clear from the fact that the decomposition of potassium chlorate is irreversable. Several workers have shown that zinc oxide, magnesia, etc., produce no facilitation and there would seem to be a possibility of chemical action in the case of every substance known to facilitate the decomposition.* For example the oxides of manganese, iron, cobalt, nickel and copper cause the oxygen to be very readily evolved, but in each case the existence of an unstable higher oxide is known or indicated.

The author has not been able to confirm Veley's statement (*loc. cit.*) concerning barium sulphate (apparently based upon a single experiment) but finds that the facilitation is scarcely noticeable and seems fully explicable by the fact that the added substance is not chemically inert, there being distinct formation of barium chlorate, a substance which decomposes more readily than potassium chlorate. The more active forms of the oxides of manganese produce very striking effects. Thus the presence of only 1 per cent of the "per-

* The effect of adding various substances to potassium chlorate has been dealt with in numerous papers, *e.g.*, Baudrimont, *J. Pharm. Chim.*, 1871, iv., 14, 81, 161; Jungfleisch, *ibid.*, 1871, iv., 14, 130; H. Schulze, *J. Pr. Chem.*, 1880, ii., 21, 426; Hodgkinson and Lowndes, *Chem. News*, 1888, 58, 309; 1889, 59, 63; Veley, *Phil. Trans.*, 1888 A, 271; Fowler and Grant, *Trans. Chem. Soc.*, 1890, 57, 272; and M'Leod, *ibid.*, 1889. 55, 184; 1894, 65, 202; 1896, 69, 1015.

oxide" precipitated from the acetate by bromine is sufficient to bring about violent decomposition of the chlorate at 340° C., although in its absence, but little change is effected by prolonged heating at this temperature.

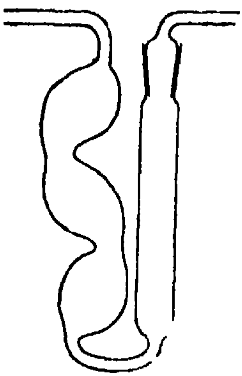
Small quantities of potassium permanganate and free chlorine are formed when potassium chlorate is heated with oxides of manganese. A study of the effects of variation of pressure was undertaken in order to ascertain whether this trace of chlorine was the entire amount evolved or a vestige of a much larger quantity which had taken part in some secondary reaction.

It was not practicable to study slow decomposition by determining the amount of oxide in the residue, as with pure chlorates, on account of the acidic properties of manganese peroxide, nor could the chlorine be directly determined in the gas if slowly evolved, as the results would then have been vitiated by the action of the chlorine on the hot glass. It was therefore necessary to render the latter error negligible by decreasing the time. A soda-glass tube of about 15 mm. bore, having at the lower end a bulb of about 28 mm. diameter, containing 1 gramme of potassium chlorate and a known weight of manganese peroxide, was furnished with an indiarubber stopper, through which passed the stem of a T-piece. One end of the top of the T was connected to a mercurial manometer indicating the pressure under which the decomposition took place, whilst the other was sealed to the tubular stopper of the first of two absorption tubes containing a solution of neutral potassium iodide. The farther limb of the second absorption tube was connected to a Fleuss pump and an exhausted four-gallon stoneware bottle when the decomposition was to take place under reduced pressure, but, for atmospheric pressure, to a tube delivering the gas below a graduated cylinder inverted over water.

In the first decompositions under reduced pressure, the rapid stream of gas carried much of the potassium iodide solution out of the absorption tubes. This difficulty was overcome by giving the bulbed ascending limb a marked zig-zag form, as shown in the accompanying figure. A com-

paratively small tube of this form will pass the full blast of an ordinary foot bellows with the loss of only a few small splashes.

In conducting an experiment, a bath of melted pewter was raised until the surface was some distance above the level of the mixture in the tube, and the pressure was then noted. After an interval, the temperature was raised until the decomposition became rapid, and the maximum pressure observed, the manometer being tapped meanwhile. In experiments under atmospheric pressure, there was but little increase. After decomposition, the tube was twice exhausted, through the potassium iodide solution, which was then titrated with $N/500$ thio-sulphate. The absorbing arrangements were sufficiently efficient, as comparatively little chlorine reached the second tube.



It seems doubtful whether anyone has obtained a substance having the exact composition required by the formula MnO_2, but all the oxides of manganese between MnO and MnO_2 facilitate the decomposition of potassium chlorate. It is stated that an intermediate oxide finally results whichever oxide is used.

The expression "manganese peroxide" will be employed in the sense of MnO, $n MnO_2$, $m H_2O$, where n is large and m small, as water is obstinately retained, even when the oxide is heated until a little oxygen has been given off.

A very active specimen of "precipitated manganese peroxide" was prepared by the action of bromine on manganous acetate at about 55° C. Its composition approximated to that required by the formula MnO, $5MnO_2$. This substance was in the form of shining black scales, so bulky that a 1 oz. bottle held only 6 grammes. In presence of 5 per cent. of this oxide the decomposition of the potassium chlorate became violent and beyond control when the temperature of the bath had risen to about 340° C.

and the rapid rush of gas lasted about a third of a minute. The average proportions of the total chlorine obtained in the free state were 0·52 per cent. under atmospheric pressure and 0·45 per cent. under 25-44 mm. Some dense manganese peroxide obtained by heating the nitrate had a composition nearly agreeing with the formula MnO_2. It was much less active than the precipitated peroxide and it was necessary to add 20 per cent. in order to readily obtain rapid decomposition of the chlorate. The rush of gas took place when the bath attained a temperature of about 350° C. and lasted about half a minute. The results were more regular than those obtained with the precipitated peroxide and the proportions of free chlorine were identical under atmospheric and reduced pressure, viz., 0·31 per cent of the total. It will thus appear that reduction of pressure did not give the slightest increase in the proportion of free chlorine.

The Nature of the Cycle of Changes.—As the oxides of manganese can be recovered from the residue and used over again any explanation of their action must be of the nature of a cycle of changes, and with only three elements in addition to manganese all possibilities would seem to be included in one or other of the following three classes:—

(1) Cycles in which the formation of a compound containing manganese and *potassium* is included.

(2) Cycles in which the formation of a compound containing manganese and *chlorine* is included.

(3) Cycles confined to alternate oxidation and deoxidation.

As an example of class (1), we may take the theory usually given in text-tooks (McLeod), it being suggested that permanganate, chlorine and oxygen are first formed, $2KClO_3 + 2MnO_2 = 2KMnO_4 + Cl_2 + O_2$, the permanganate then breaks up approximately in accordance with the equation $2KMnO_4 = K_2MnO_4 + MnO_2 + O_2$, and nearly all the chlorine reacts with the manganate, $K_2MnO_4 + Cl_2 = 2KCl + MnO_2 + O_2$. The experiments of McLeod and others tend to indicate that a trace of permanganate is formed, and that all these reactions *may* occur during a decomposition, but

the author is not aware of anyone having attempted to show that these changes *do* actually occur to any considerable extent. It is easy to devise similar cycles in which the first reaction produces manganate or manganite instead of permanganate.

If the breaking up of the chlorate be due to a cycle of this class, the whole of the chlorine must be progressively liberated and all except a trace must be reabsorbed.

To illustrate class (2), suppose the very unstable manganous chlorate were formed, this would immediately break up, yielding much free chlorine,* and any resulting manganous chloride would at once be violently converted into peroxide by the action of the heated chlorate.† Here again, the whole of the chlorine would be liberated, but reabsorption might be brought about by the potassium oxide first formed. It seems unlikely that there should be any marked formation of manganous chlorate, for it has been repeatedly shown that neither magnesia nor zinc oxide produces any appreciable acceleration in the reaction, although both are far more basic than the oxides of manganese.

It will be seen that cycles belonging to class (3) are the only ones which do not involve the setting free of the whole of the chlorine contained in the chlorate, coupled with an almost complete reabsorption.

In the preceding sections it has been shown (as may be seen from the Table, p. 116) that with the chlorates of (potassium) barium and calcium, reduction of pressure causes no increase in the proportion of free chlorine, but in the decomposition of lead chlorate and of silver chlorate, where there is a secondary reaction removing free chlorine from the gaseous products, reduction of pressures results in a large additional quantity of chlorine remaining in the free state, an example of the well-known effect of decrease of the concentration (or pressure) of a gas which is reacting with a solid or liquid. Had the presence of oxides of manganese resulted in the intermediate liberation of the whole of the

* Wächter, *J. Pr. Chem.*, 1843, 30, 325.

† H. Schulze; M'Leod, 1889, *loc. cit.*

chlorine in the potassium chlorate (as required by cycles of classes 1 and 2), the behaviour of the mixture should in this respect have been comparable with that of silver chlorate. On the contrary, however, reduction of pressure did not produce the slightest increase in the amount of chlorine remaining free, or, in other words, the production of chloride proceeded to the same extent. There is therefore no secondary reaction removing liberated chlorine and cycles of classes (1) and (2) are excluded, the changes being limited to oxidation and deoxidation

The action of one or more of the acidic oxides MnO_2, MnO_3 or Mn_2O_7 on potassium chlorate seems to account sufficiently for the production of the trace of chlorine, but there is, in addition, the bare possibility of the formation of traces of chlorate or chloride of manganese from which chlorine would be rapidly expelled.

Nature of the Substance which actually causes the Facilitation.– It seems unlikely that the manganese compound, acting as an "oxygen-carrier," should contain chlorine, on account of the smallness of the proportion of free chlorine and the readiness with which chlorine is evolved from chlorate or chloride of manganese. As the amount of liberated chlorine in the gas is so small, only traces of any compound containing potassium and manganese can be present under ordinary conditions, but much more would be formed on adding a little potassium carbonate, which, however, greatly retards decomposition,* or by replacing manganese peroxide by potassium permanganate, but this is actually much less active; † it therefore seems certain that the substance taking part in the cycle is not a potassium compound.

By this process of exclusion, it would appear that the actual oxygen-carriers must be the oxides of manganese. This being so, addition of an alkali would be expected to produce a retardation by converting the most active particles into manganate. The evidence at present available appears

* Jungfleisch; M'Leod, 1889, *loc. cit.*

† Baudrimont; M'Leod, 1889, *loc. cit.*

to afford only an indication of the probable limits between which oxidation and deoxidation proceed Jungfleisch (*loc cit*) and others regard the production of the trace of permanganate as indicating the formation of Mn_2O_7 but in order to establish such a view it must be shown that the combination with potassium does not precede the oxidation

Oxides of manganese markedly facilitate the decomposition of other chlorates for example those of barium and calcium The mechanism of these actions is probably similar to that described above but the author has not made any detailed investigation of these cases

EFFECTS OF VARIATION OF PRESSURE AND RATE OF DECOMPOSITION

Chlorate	Duration of Experiment in Minutes*	Pressure	Chlorine (total 100) As Chloride	Chlorine (total 100) Free	Additional Chlorine under Reduced Pressure	Mols Chloride / Mols Oxide
Potassium	280	1 atm	100.00	0.00		> 50,000
	280	1 mm	100.00	0.00	nil	> 50 000
Barium	0	1 atm	99.296	0.704	—	141
Barium	165	1 atm	99.907	0.093		1 077
	233	1.2 mm	99.934	0·066	nil	1 513
Calcium	0.1	1 atm	97.82	2.18	—	45
Calcium	130	1 atm	99.42	0.58	—	171
	100	4 mm	99.46	0.54	nil	185
Lead	(explosion)	1 atm	61.4	38.6		1.59
		6.16 mm	41.3	58.7	20.1	0.703
Lead	40	1 atm	52.0	48·0		1.08
	90	20.25 mm	24.7	75.3	27.3	0.33
	110	1.2 mm	18.6	81.4	33.4	0.228
Silver	(explosion)	1 atm	93.3	6.7		13.9
Silver	110	1 atm	99.8	0.2		500
	70	20 mm	93.25	6.7	6.55	13.8
	140	2½ mm	77.4	22.6	22.4	3.42
Potassium with 5 per cent ppd MnO_2	about 0.3	1 atm	99.48	0.2		—
		25.44 mm	99.55	0.45	nil	—
Potassium with 20 per cent MnO_2 from nitrate	about 0.5	1 atm	99.69	0.31	—	—
		25.45 mm	99.69	0.31	nil	

* The numbers in this column are intended only as a rough indication of the rate at which the decomposition was conducted They afford no indication of relative ease of decomposition In most experiments some of the Chlorate was allowed to remain undecomposed Fuller information will be found in the papers quoted on p 104

PRINCIPAL CONCLUSIONS. (See also Table above.)

A.—Decomposition of Chlorates when Heated Alone.—Of the six reactions (p. 107) which might give rise to the evolution of chlorine and oxygen, only three have been found to actually occur. Direct decomposition into chloride and oxygen occurs in the case of the chlorates of potassium, barium, calcium, lead (and silver ?), whilst decomposition into oxide, chlorine, and oxygen definitely occurs with barium, calcium, lead and silver; in the case of lead and silver, much of the chlorine reacts with the oxide, giving chloride and oxygen. No evidence of the expulsion of chlorine from chloride has yet been obtained, and it does not take place with potassium, barium, calcium, lead and silver. The direct formation of both oxide and chloride does not necessarily imply that the chlorine is labile, or attached to the metal (isochlorate) in some molecules at the temperature of decomposition: both decompositions may be illustrated as under, using the ordinary general formula $MOClO_2$, where M is a monatomic metal -

$$\text{(chloride)}\ \frac{\text{M O Cl O}_2}{\text{O}_2\text{Cl O M}} \qquad \text{(oxide)}\ \frac{\text{M O Cl O}_2}{\text{M O Cl O}_2}$$

The fact of chlorine being split off and then immediately acting on the residual metallic oxide seems to fairly satisfactorily prove that the metal in lead chlorate and silver chlorate is directly attached to oxygen at the temperature of decomposition.

When potassium chlorate is heated by itself, perchlorate is formed by self-oxidation, a process not *essentially* connected with the evolution of oxygen. It seems highly probable that a similar action occurs whenever a perchlorate is formed during the decomposition of a chlorate.

In the general case of the decomposition of a chlorate $MClO_3$, there are therefore four reactions, viz. :—

(*a*) $2MClO_3 = 2MCl + 3O_2$.

(*b*) $2MClO_3 = M_2O_2 + Cl_2 + 2O_2$ *or* $2MClO_3 = M_2O + Cl_2 + 2\frac{1}{2}O_2$.*

(*c*) $M_2O_2 + Cl_2 = 2MCl + O_2$ *or* $M_2O + Cl_2 = 2MCl + \frac{1}{2}O_2$.*

(*d*) $MClO_3 + 3MClO_3 = MCl + 3MClO_4$.

* For convenience of comparison these two equations have not been doubled.

Reactions (*a*), (*b*) and (*d*) are independent of each other, but (*c*) necessarily depends partly upon (*b*); the relative velocities vary greatly according to the strength of the base, and are also affected by temperature (notably with barium chlorate where (*a*) and (*b*) are thermally opposite in sign); reaction (*c*) is affected also by variations of pressure, or by the presence of an inert gas.

The above theory appears to be the only one which will accord with all the facts with which the author has become acquainted during a fairly extensive search of the literature of chlorates, as well as with the whole of the present investigation.

The average relative velocities of the four reactions are given below.

Chlorate of—	Potassium.	Barium	Calcium	Lead	Silver
Slow decomposition.					
(*a*) Chloride and O	unit	unit	unit	unit	unit
(*b*) Oxide, Cl and O	$<0{\cdot}00002$	0·0008	0·006	7	$>0{\cdot}55$
(*c*) Cl acting	improbable	negligible	negligible	high	very high
(*d*) Perchlorate	1·2 -2·95	1	0·036	very low	—
Rapid decomposition					
(*b*) Oxide, Cl and O		0·007	0 02	>7 (?)	probably high

B.—Potassium Chlorate in presence of Oxides of Manganese.

(1) The facilitating action of the oxides of manganese is due to the formation of a higher oxide of manganese by the oxidising action of the heated chlorate and the subsequent breaking up of the higher oxide.

The first action may be represented by the equation

$$\frac{n}{3}KClO_3 + MnO_m = \frac{n}{3}KCl + MnO_{m+n}{}^*$$

and the second stage by $2MnO_{m+n} = 2MnO_m + nO_2$

$$or \ \frac{n}{3}KClO_3 + MnO_{m+n} = MnO_m + \frac{n}{3}KCl + nO_2$$

* Where *m* and *n* are not necessarily whole numbers.

according as the unstable higher oxide has or has not the power of reducing potassium chlorate by virtue of the greater stability of molecular oxygen and the lower oxide.

The limits between which these changes occur have not yet been determined, and the production of traces of potassium permanganate does not establish the formation of Mn_2O_7. The manganese compounds which actually cause the facilitation do not appear to contain either potassium or chlorine.

(2) The liberation of a little chlorine is not an essential part of the cycle of changes bringing about the facilitation. It seems to be amply accounted for by the action of MnO_2, MnO_3, or Mn_2O_7 on potassium chlorate or chloride with the additional bare possibility of the formation of traces of the chlorate or chloride of manganese.

(3) The supposed ability of chemically inert solid particles to facilitate the decomposition of potassium chlorate does not appear to be supported by any experimental evidence, and if existing is inadequate to explain even a small fraction of the great facilitation produced by oxides of manganese, iron, cobalt, nickel, and copper.

(4) Addition of manganese peroxide prevents the production of perchlorate by bringing about the decomposition into chloride and oxygen at a temperature much below that at which self-oxidation of the chlorate proceeds at an appreciable rate.

The Geological History of the Tyne, Wear and Associated Streams.

By D. Woolacott, M.Sc

[Read March 6th, 1903.]

It is now generally admitted that the rivers of any district have in the majority of cases passed through several stages of growth and development.* It is my purpose in this paper to trace as far as possible the development of the Tyne and Wear, and the smaller streams associated with them.

The Pennine chain, consisting of a faulted anticlinal of Carboniferous rocks, forms the most important feature in the drainage system of Northumberland and Durham. This range, together with the Cheviots, has probably been exposed since Permian times, and hence the determining features of the head waters of the North and South Tyne, the Wear and the Tees were in all probability formed during the Mesozoic ages. It would seem as if the uprise of the Pennines had been accentuated in the Crossfell area, and hence the Tees, Wear and South Tyne all rise in that district, having been developed from a centre. An interesting point worthy of discussion in this connection is the origin of the so-called Tyne gap, which is a valley cutting across the Pennines at a level of less than 500 feet. The railway from Newcastle to Carlisle runs through this gap. Mackinder in his *Britain and the British Seas* suggests that the source of the Tyne once lay in the region of the Solway Firth, and that the Nith and the Annan were its former head waters.† The Eden, which is a river of later development cut out in the soft and unresisting New Red deposits, has caught up these head waters. The proof of such a suggestion is hardly

* *Introduction to Geological History of Rivers of East Yorkshire*, by F. R. Cowper Reed.

† *Britain and the British Seas*, by H. J. Mackinder, pages 55 and 128.

possible, yet it offers a very feasible explanation of the facts. It may be, however, that this gap is due to a former tributary of the Tyne occupying the Irthing valley, now a confluent of the Eden, but which has been proved to have been, even in post-glacial times, a tributary of the Tyne.* The South Tyne, a dip stream flowing from the Crossfell area, would be tributary to this easterly flowing stream. The Tyne, which flows in the easterly continuation of this gap, is from Haltwhistle to near Hexham a strike stream.

The Permian rocks were in all probability deposited over a large portion of the east and south of Northumberland and Durham, but the limits of their deposition is hardly possible of determination, and still more difficult is it to determine the limits of deposition of the secondary rocks over this area. Jukes-Browne in his *Building of the British Isles* discusses this thoroughly, and as it is impossible to enter more fully into it in this paper, the reader is referred to this work for the discussion of this portion of the subject. Cowper Reed in his *Geological History of the Rivers of East Yorkshire* also discusses this subject.

In the north-eastern counties of England probably the most extensive of all the secondary formations was the Upper Chalk, which was, according to some authors, deposited in Yorkshire at any rate, right up to the foot of the Pennines, and thus we are probably right in asserting that the greater portion of the south and east of Northumberland and Durham was under water at this time. Denudation was probably still proceeding on the Pennines, and the rivers of the first cycle, which had been developed during the interval between the Permian and the Cretaceous, may have been to a certain extent betrunked.

It will, however, be clear that of this first cycle of river development very little trace can be left, except that the heads of the main valleys may have been to a certain extent determined; and in the second cycle these already existing valleys became again the natural waterways, and were cut deeper as the rivers received new life due to the post-Cretaceous uplift.

* Professor Lebour's *Geology of Northumberland and Durham.*

This uplift occurred after the deposition of the Upper Chalk, and made Britain throughout Tertiary times more or less a part of the European continent and the greater part of the area now occupied by the North Sea dry land.* The upward movement was greater towards the west, and hence the land sloped from the Pennines gently towards the east, corresponding roughly with the dip of the beds. A new era in the development of the rivers of the north-eastern counties would begin and a system of dip and subsequent streams would be started, which would be the direct ancestors of the present ones. This is the second important cycle in the development of the rivers of Northumberland and Durham. The constructional shore-line probably lay far to the east of the present east coast of England, and indeed at one time the rivers flowing down the east slope of the Pennines may all have been tributaries of a major one flowing down the east of the North Sea area. Most of the smaller streams developed during this epoch have been totally obliterated by their valleys being filled with drift during the glacial period, and also many of the larger streams have had their courses changed; but we shall discuss this interesting subject later.

Cowper Reed has been able to trace out many minor changes in the development of the rivers of Yorkshire during Tertiary times, but of such changes in the district under our notice nothing can be asserted.

In the *Geological History of the Rivers of East Yorkshire* the same writer shows that the Wear was possibly a tributary of the Tees, and this would probably be so, because at one time the Wear would be throughout its course a dip stream, and hence may have flowed over the Carboniferous and Permian outcrops, and thus may have been tributary to the Tees. The Wear was, however, probably beheaded by a subsequent of the Tyne which had been developed along the edge of the outcrop of the Permian rocks from the Tyne south-eastwards. In this way, the Cleadon

* *Introduction to Geological History of Rivers of East Yorkshire*, by F. R. Cowper Reed, page 28.

valley may have been begun* but afterwards the Wear was cut off by a tributary of the Tyne, which had been gradually cut back along the line of the present Team valley. This valley, now known as the Wash, is filled with superficial glacial and post-glacial deposits. It was most minutely described by Messrs. Wood and Boyd in the *Transactions* of the North of England Institute of Mining and Mechanical Engineers (vol. xiii.). The Cleadon valley was probably still further deepened by a small tributary of the Tyne before glacial times, and hence immediately before the glacial period the Wear probably flowed down the "Wash," and a small tributary of the pre-glacial Tyne down the Cleadon valley. It seems to me that in this manner we can account for the peculiarities of the pre-glacial valleys discussed in a paper published in a former volume of these *Transactions*.†

The Tees, which in Tertiary times flowed through the Cleveland district right across the Oolitic and Liassic outcrops in the line of the Leven and the Esk, may also have been captured by a subsequent, which had worked back along the Triassic outcrop,‡ similar and roughly parallel to the one that had diverted the Wear along the outcrop of the Magnesian Limestone.

The next cycle in the development of the rivers of Northumberland and Durham commences with the passing away of the Ice Age. The ice filled up their valleys and checked their development; and after its disappearance all the lower parts of the pre-glacial valleys were filled up with deposits of boulder clay, sand and gravel. The ice itself had probably done little or no erosion, and except that it had polished and rounded off the sides of the valleys, it had had little or no effect in altering their course. In many of the valleys such as the East and West Allen, the Devil's Water and the Derwent, glacier lakes had been formed, and the over-

* "On the Boulder Clay, Raised Beaches and Associated Phenomena in the East of Durham," *Proceedings of the University of Durham Philosophical Society*, vol. i., p. 247.

† *Ibid.*

‡ *Introduction to Geological History of Rivers of East Yorkshire*, by F. R. Cowper Reed, page 61.

flow channels of many of them, although now quite dry, can be distinctly traced. These have been thoroughly discussed by Captain Dwerryhouse in the *Quarterly Journal* of the Geological Society.* I have lately been over the Devil's Water and Beldon Burn district and I am in agreement with Captain Dwerryhouse's interpretation of the facts.

When the glacial period was over, the larger valleys were partly filled with drift and many of the smaller ones were totally obliterated. The course of the streams that formed on this newly-formed land surface was therefore in many cases totally different from that of the pre-glacial ones. The surface on which the rivers of this third cycle developed was composed of rock and boulder clay and in many cases the river has preferred to cut its way through rock rather than boulder clay. The changes that took place in the course of the rivers were thus very great, and in many cases entirely new valleys were cut.

The Wear has developed almost entirely through rock a new course from Durham to Sunderland since glacial times, while the Team now flows in the old pre-glacial Wear valley over a thick series of superficial deposits. The Don flows over boulder clay into the Tyne at Jarrow Slake. The Tyne also, although flowing in the general course of the pre-glacial valley, has changed its course considerably, as can be easily proved by a consideration of the borings and sinkings in the course of it. This can be clearly seen in the accompanying map and section. A pre-glacial valley also enters the Tyne valley from the north near Newcastle. The Ouseburn now flows roughly in the course of this old valley.

MAP OF TYNE VALLEY FROM NEWBURN TO ITS MOUTH, SHOWING BORINGS IN ITS COURSE.

		Level.	Superficial deposits.
A.	Newburn	24	82
B.	Blaydon	10	97
C.	Norwood New Pit	16	156
D.	Newcastle (High Level)	0	52
E.	Jesmond	60	72
F.	Felling (Venture Pit)	75	132
G.	Walker (Resolution Pit)	135	80

* *Quarterly Journal of Geological Society*, vol. lviii., No. 231.

MAP OF THE TYNE VALLEY FROM NEWBURN TO ITS MOUTH.

		Level	Superficial Deposits
H	Low Walker	60 (?)	138
I	Hebburn	80	88
J	Flatworth Pit	142	158
K	Howdon Old Pit	50	101
L	Percy Main	100	193
M	Chirton	102	191
N	Burdon Main	50	191
O	Cullercoats	110	21
P	Templeton Colliery	17	65
Q	Harton Colliery	77	90
R	Boldon Colliery	100	95
S	Bigges Main	130	102
T	Wallsend	72	170
U	Hebburn	80	59
V	St Hilda's	30	53

Shading indicates parts of country where rock comes to surface other parts covered by drift

Depth of rock surface above sea level

Depth of rock surface below sea level

X Y Line of Section

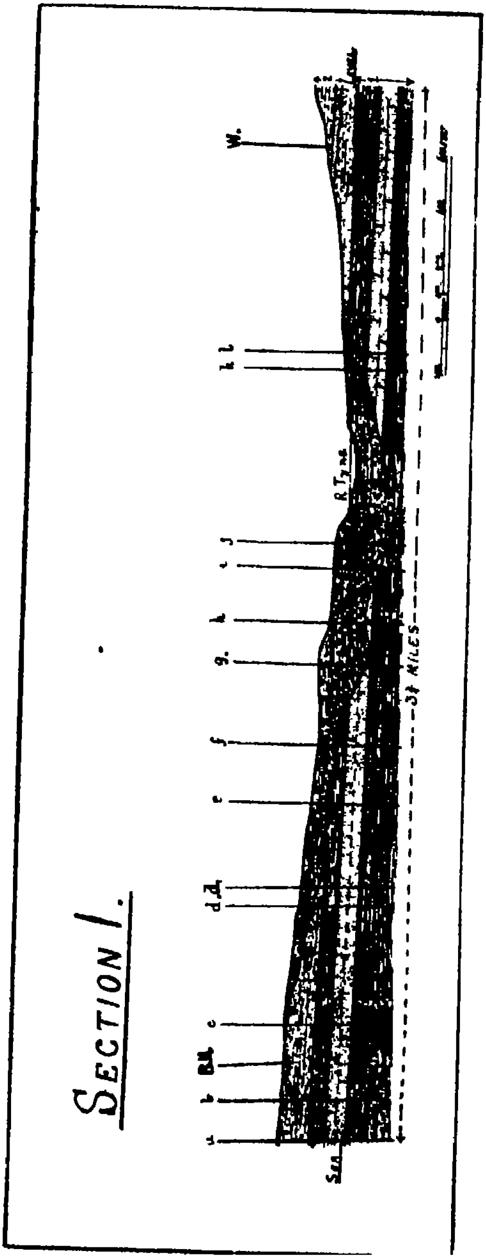
Arrows indicate probable direction of pre glacial streams

SECTION FROM BILLY MILL TO WESTOE ACROSS TYNE VALLEY

		Level	Superficial deposits
(a)	Moor Houses	230	6
(b)	Billy Mill	215	15
(c)	Chirton Hill	201	5
(d)	Chirton	180	42
(d_1)		153	64
(e)	Chance Pit	130	60
(f)	Hopewell Pit	100	60
(g)	Low Chirton	102	191
(h)	Chirton	60	111
(i)		62	119
(j)	Burdon Main	50	191
(k)	St Hilda's	90	53
(l)	,,	40	35

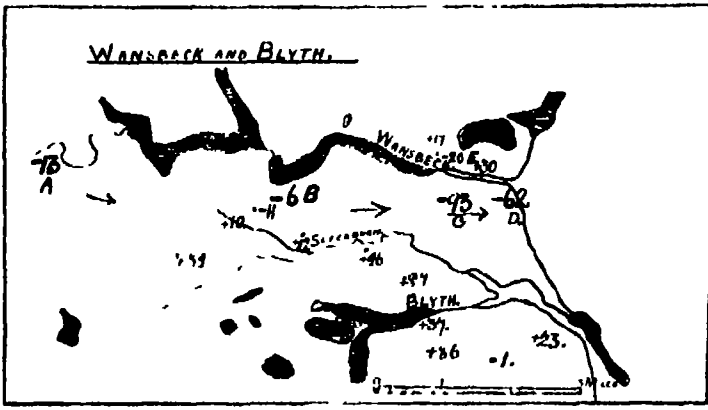
Section is through Coal measures (1) and Permian (2)

To the north the Blyth and Wansbeck, and the other streams are all post-glacial and have cut new courses largely through rock since the glacial period A pre-glacial valley, which we shall call the Sleekburn valley, runs down between the Blyth and the Wansbeck The map of these two valleys, showing the two rivers and the principal borings, brings out clearly the relation of the pre-glacial and the post-



SECTION FROM BILLY MILL TO WESTOE ACROSS THE TYNE VALLEY.

glacial valleys. Nothing can give a better idea of the amount of denudation that has gone on since the passage of the glacial period than a walk down the Wansbeck from Morpeth to its mouth. The straight-cut deep valley bears evidence of rapid denudation due to stream action, and is post-glacial.



MAP OF WANSBECK AND BLYTH VALLEYS, SHOWING BORINGS IN THEIR COURSE.

		Level	Superficial deposits.
A.	Morpeth	90	103
B.	Choppington	105	116
	"	120	126
C	Sleekburn	50	143
D.	Cambois	28	90
E.	Blackclose, North Seaton	50	70

Shading indicates parts of country where rock comes to surface, other parts covered by drift

+ Height of rock-surface above sea-level.

− Depth of rock-surface below sea-level.

The land probably after the close of the glacial period stood much higher than at present, and therefore the development of the rivers would be to a certain extent checked by the period of submergence indicated by the raised beaches of the district. It was probably during this period that the surface of the boulder clay in the east of Northumberland was made so even and flat, and all traces of the original ridge-

Notes on Durham College Founded by Oliver Cromwell.

By the Very Rev. G. W. Kitchin, D.D.

[Read May 14th, 1903.]

In August, 1640, Bishop Morton withdrew into Yorkshire and Archdeacon Belcanquel fled in great haste, as did also "all the rest of the clergy of Durham;" the Scots employed men to receive their rents, for the use of their army.

From this time the precincts of the Cathedral lay waste till 1657. Bishop Morton's whole revenues were taken by the Parliament in 1646, and a pension of £800 a year was given to him. Of the properties sold in 1647

Sir Arthur Hazelrigge bought four:—

	£	s	d.
Bishop Auckland Manor	6,102	8	11½
Bishop Middleham Manor	3,306	6	6½
Easingwood Manor	5,833	7	9
Wolsingham Manor	6,764	14	4
	£24,006	17	7

The chief documents relating to this College are the following:

1.—A petition to Parliament, 7th May, 1650. This was delivered by the Grand Jury at the gaol-delivery to the High Sheriff, James Clavering, Esq.

Praying—That a re-establishment of Courts of Justice might be had:

And that the College and houses of the Dean and Chapter, then empty and going to decay, might be employed for erecting a college, school or academy, for the benefit of the Northern Counties, which were so far distant from

the universities; and that part of the lands of the said Dean and Chapter near the City might be applied by Trustees to pious usages.

2.—A Committee of the House followed; it reported favourably.

3.—Then came Oliver Cromwell's letter to Speaker Lenthall, dated Edinburgh, 11th March, 1651 (a document said to be in custody of the Dean and Chapter, but now not to be found): --

TO SPEAKER LENTHALL.

"EDINBURGH,

"11*th March*, 1651.

"SIR,

"Having received information from the Mayor and citizens of Durham, and some gentlemen of the Northern Counties, that upon their petition to the Parliament, "that the houses of the late Dean and Chapter in the city of Durham might be converted into a college or school of literature," the Parliament was pleased in May last to refer the same to the Committee for Removing Obstructions in the sale of Dean and Chapter lands, 'to consider thereon, and to report their opinion therein to the House,' which said Committee, as I am also informed, have so far approved thereof that they are of an opinion that the said Houses will be a fit place to erect a college or school for all the sciences and literature, and that it will be a pious and laudable work and of great use to the Northern parts; and have ordered Sir Arthur Hazelrigg to make report thereof to the House accordingly, and the said citizens and gentlemen having made some address to me to contribute my assistance to them therein:—

"To which, in so good and pious a work, I could not but willingly and heartily concur. And not knowing wherein I might better serve them or answer their desires, than by recommending the same to the Parliament by, Sir, yourself their speaker—I do therefore make it my humble and earnest request that the House may be moved, as speedily as conveniently may be, to hear the Report of the said

Committee concerning the said business, from Sir Arthur Hazelrigg; so that the House, taking the same into consideration, may do therein what shall seem meet for the good of those poor counties.

"Truly it seems to me a matter of great concernment and importance; as that which, by the blessing of God, may much conduce to the promoting of learning and piety in those poor, rude and ignorant parts; —there being also many concurring advantages to this place, as pleasantness and aptness of situation, healthful air, and plenty of provisions, which seem to favour and plead for their desires therein. And besides the good, as obvious to us, which those Northern Counties may reap thereby, who knows but the setting on foot this work at this time, may suit with God's present dispensations; and may—if due care and circumspection be used in the right constituting and carrying on the same,—tend to, and by the blessing of God produce, such happy and glorious fruits as are scarce thought on or foreseen!

"Sir, not doubting of your readiness and zeal to promote so good and public a work, I crave pardon for this boldness; and rest

"Your most humble servant,

"OLIVER CROMWELL."

Parliament took it in hand on the 18th June, 1651. But it had in the end to wait till Oliver Cromwell became Lord Protector, some seven years later, when, as Carlyle, writing in 1845, says in his way, the Protector "actually began giving lessons on human grammar, human geography, geometry, and other divine knowledge to the vacant human mind--in those once sleepy edifices, dark heretofore, or illuminated mainly by Dr. Cosin's papistical waxlights or the like; and so continued, in spite of opposition, till the Blessed Restoration put a stop to it, and to some other things. In late years there is again some kind of Durham College giving lessons—I hope with good success."

This letter was strongly backed by the people in 1652 and 1653 (signed among others by Wm. Wharton, Cuthbert Rayne and J. Joplin).

For, as Mr. Morley says,* when speaking of Durham College, "Cromwell had compass of mind enough to realise the duty of a state of learning, but the promotion of religion was always his commanding interest."

4.—The Grand Jury of Durham sent in the following paper, dated 14th January, 1651-2:—

"The Humble desires and representacion of the gentlemen, freeholders and inhabitants of the Countie and city of Durham . . . .

"SHEWETH—That your peticioners doe with all humility and thankfulness acknowledge your honour's pious care to the publique and especial favours and respect towards your peticioners in your late concessions for founding of a colledge at Durham, and in granting the colledge of the late Deane and prebendes houses there to that purpose, were amidst the great and weighty affairs of the Commonwealth, and for the better encouragement of men of piety and good parts, and support of those not able to maintaine themselves—your peticioners to manyfest their desires to promote soe laudable a worke with least change to the Commonwealth did by their former representacion from the last assizes holden at Durham in August, 1650, humbly crave, that a competent revenue in lands might be granted to the said use, in consideration of a debt of £25,663 13s. 10d. remaining yet due to this county and city since November, 1641, by order of this honourable house hereunto annexed, and that it may the better appeare to be a worke so pious, laudable and convenient for this Commonwealth, especially the northerne countyes—your peticioners doe with all humility offer to consideracion the reasons hereunto annexed, and doe again desire

"That this great court would be pleased to grant some competent revenue in lands for founding of the said colledge, and the said debt to be allowed in the purchase thereof, without doubling of the same; and to appoint some competent number of worthie and faithful gentlemen of the said

* *Oliver Cromwell*, p. 429.

county and city that may be Commissioners for formeing and establishing the said colledge with such locall statuts and good orders, as may most conduce to the accomplishment of those honorable ends of advanceing piety and learning intended by your honours, And it will be a lasting monument of your pious care to promote soe valuable a worke, and more endeare your peticioners ever to pray, that wisdom, truth and prosperity may direct and attend your Commonwealth." (Signed by 17 persons.)

5.—This document was referred to a Committee of the House which reported that it would be a fit place to erect a college or school for all the sciences and literature; that it would be a pious and laudable work, and of great use to the northern parts; it ordered Sir Arthur Hazelrigg to make their Report to the House

6.—28th April, 1653. The inhabitants addressed the Government in the new form, viz.: "The Lord Generall and the rest of his Councell of Officers."*

In reply to a declaration from Government, 26th April, 1653, they write, "upon the reading whereof we were at first like men in a dreame and could hardly beleeve for rejoycing, to see the wonderful goodness of God, in renueing a remembrance of your former engagements for this poore nation" . . . wee make bold, in the behalfe of many hundred honest hearts in this country, being desired by many of them to write to you, to let you know how much we desire to blesse God for still owneing you, and to shew you how much our hearts owne you in this action of late. . . . . And were it not tedious to present some overtures we should make bold to speak something for this poor county, which hath for a long time layd under many oppressions; and the more, for that by the usurpation and the pride of the bishops there never was that liberty given us for the choyce of parliament men to speake out our grievances, or to attempt our deliverance, suitable to all other countyes in the nation."

* Dissolution of the Long Parliament, April 20th, 1643. The *régime* of the Major Generals begins with the dissolution of the Barebones Parliament, December 12th, 1653.

About this time a strong opposition to the proposed college appeared. J. Conant, Rector of Exeter College, Oxford, is stated to have succeeded in preventing Oliver Cromwell from making a University at Durham, "setting forth the dangers which threaten religion and learning by multiplying small and petty Universities."

It is curious to read in Duke's *Life of Fox* (p. 140) how jealous all sorts of people were of it.

"Coming to Durham, they met with a person lately arrived from London, with an intention to establish a College for preparing young men for the Ministry. George [Fox] visited this man, and reasoned with him on the insufficiency of human learning for making a Gospel Minister. The man assented to much of what George said, was very tender, and ultimately declined to set up his College."

One sees the same suspicion in Milton:* "Honest and ingenious natures, coming to the Universities to store themselves with good and solid learning, are there unfortunately fed with nothing else but the scragged and thorny lectures of Monkish and miserable sophistry—and so were sent home again with such a scholastic *burr* in their throats as hath stopped and hindered all true and generous philosophy from entering."

There is a trace of this resistance in the Vice-Chancellor of Oxford's books for 1658-1659, "for the copies of 2 patents concerning the College at Durham, and for other fees to clerkes, 2*li.* 10s.; to Mr. (Antony) Fidoe for writing four copies of the University petition and reasons against erecting a University at Durham, 2*li.* 10*s.*; to Dr. (Daniel) Greenwood and Dr. (John) Wallis for the charge of their journey to London for preventing the erecting of the Universitie at Durham, 16*li.*"†

We now arrive at the actual beginnings of this College.

7.—In an Order of 18th February, 1657-8, I find it stated that in 1655 [? 1656] "Whereas his Highness the Lord

* *Reason of Church Government.*

† Wood's *Life and Times*, vol. iv. (Add.), p. 63; and additional note to I. 216.

Protector and the Counsel have on 1 Feb. 1655-6 ordered that the yearely summe of £282 4s 4d. should be allowed by way of Augmentation to three able and godly Preachers, members of the Colledge by the same order mencioned to be founded w^th in the city of Durham, etc."

This document is in the Lambeth Library and is endorsed

DURISME

COLLEDGE.

In the same series are orders for the help of Durham School, for Almsgiving and Charities.

8.—The great piece, however, is the Charter of Oliver Cromwell, dated 15th May, 1657, 9 v.

At the top is an emblazoned capital letter, with a hideous portrait of Oliver Cromwell and a curious Coat of Arms for England, Scotland and Ireland with the St. George's cross in the first and fourth quarter, the St. Andrew's cross in the second, and the Irish harp in the third.

These Letters Patent are dated 15th, May, 1657. "For founding a College at Durham as well with reference to the promoting of the Gospel, as to the religious and prudent education of young men there." The Charter hands over the College and Houses of the Cathedral Church and the Castle to the following body:—1 Provost or Master, 2 Preachers or Senior Fellows, 12 other Fellows (*i.e.*, 4 Professors, 4 Tutors, 4 Schoolmasters), 25 Scholars, 12 Exhibitioners, 10 School Scholars.

The first members were:—*Philip Hunton, first Provost or Master; Wm. Spinedge and Joseph Hill, M.A., Preachers or Senior Fellows; four Professors: Th. Vaughan, M.A., J. Kiffler, M.D., Robt. Wood, M.A., and John Peachil, M.A.; four Tutors: Rich^d Russell, M.A., John Richell, John

* A Hampshire man; M.A. of Wadham College, Oxford; Vicar of Westbury, Wilts; distinguished himself by looking out the incompetent ministers; after 1660 returned to Westbury; was ejected 1662; wrote controversial treatises on monarchy.

Doughty and *Ezerel Tong, D.D.; and four Schoolmasters: Lionel Wastel, Nath. Vincent, M.A., Wm. Corker, and Wm. Sprigg.

Possessions:—College, Cathedral and Castle. Rent of £117 15s. 8d. from Gateshead; rent of £500 from Gateshead; rent of £282 4s. 4d. for Dean and Chapter, Rectories and Impropriations; a yearly rent, £6,000; total £6,900: also, the Cathedral Library and the Common Seal.

Papers in the Lambeth Library (995 p. 80) shew that the organisation was still going on.

February 18th, 1657-1658. The three able and godly preachers were to have £282 4s 4d. (mentioned before) and to preach upon the Lord's Day within the city or county of Durham.

16th April, 1658. Under head of Margaret's, Durham, it is ordered that one third of above be paid (viz., £94 1s. 5¼d.) to Ezerell Tong, D.D., nominated minister of the Parish Church of Margaret's, Durham.

24th September, 1658, Mr. Philip Hunton, Provost of the said College, and Mr. Wm. Spinage are named as preachers in the Cathedral Church and City of Durham and Ezerell Tong for Margaret's, and are to have the £282 4s. 4d. in three equal parts.

March 9th, 1659. To Mr. Joseph Hill, minister of Oswald's in Elvett, is granted £120 6s. 0d.

April 16th, 1658. The one third of this sum of £282 4s. 4d. is granted to Ezarell Tong, D.D., "one of the members of the said College," on this day nominated and appointed minister in the Parish Church of Margarett in Durham.

September 24th, 1658. Mr. Philip Hunton, Provost of the said College, and Mr. Spinage, one of the Senior Fellows, are Preachers in the Cathedral Church and City of Durisme —Tong for "Margaretts"—and finally (March 9th, 1658) Mr. Joseph Hill is Minister of "Oswald's in Elvett."

* Ezerel Tong, D.D. (of Oxford, not of Durham as is sometimes said); an ally afterwards of Titus Oates; a gardener and a chemist, a man full of projects and notions, "a very mean divine and seemed credulous and simple, but I looked on him as a sincere man." At Oxford he burnt an effigy of the Pope, with cats and rats in it (!) to represent devils.

This seems to be the only outcome of this University or College of Durham—the three preachers; Cathedral; St. Margaret's; St. Oswald's. For there is no notice of any other work; and Oliver Cromwell died September 3rd, 1658.

On the proclamation of Richard Cromwell as Protector, on 4th September, 1658, there was presented a warm petition for the continued help and support of the College. Hutchinson (I., 530) ventures to say:—"This Orphan College thrived apace, it endeavoured to confer degrees, and mimic its grown-up sisters of Oxford and Cambridge, who checked its presumptions by petitions to the new Protector. But in less than two years the ill-patched machine of government fell to pieces, and with it this new Seminary of knowledge."

So comes to an end without any real life in it, the Puritan College of Durham. I do not know that even a single sermon of those preached by the three godly preachers survives. The old *régime* began again; with the old quarrelling in Bishop Cosin's days, as we see from the lives of Dean Dennis Granville and, a little later, of Peter Smart. All one can say, by way of an epitaph, is that the short life of this puny College shews something of Oliver Cromwell's interest in higher things. The Restoration, in this respect at least, was no gain. No more word about education was heard.

THE CHARTER OF OLIVER CROMWELL, FOR THE FOUNDATION OF A COLLEGE AT DURHAM.

Oliver, Lord Protector of the Commonwealth of England, Scotland, and Ireland, and the dominions thereto belonging, to all to whom these presents shall come, Greeting.

Whereas it hath been represented unto us by our right trusty and well-beloved Councillor, John Lambert, and our right trusty and well-beloved General Mountague, and our right trusty and well-beloved Francis Rowe, Esquire, a Committee of our Council (to whom the Petitons of the Justices, Grand Juries, Gentlemen and Inhabitants of our Citty and County of Durham, County of Northumberland,

and Town and County of Newcastle-upon-Tyne, for the founding of a Colledge at the Citty of Durham, was referred by our said Council), that the founding of a Colledge at Durham will be of great advantage to those counties, and to all the Northerne parts of this Island, as well in reference to the promoting of the Gospell as the religious and prudent educacon of young men there. And it having thereupon beene ordered by Us and Our Council according to the opinion of the said Committee in pursuance of the Peticioners desires That a Colledge be erected and founded at Durham, Know yee therefore that Wee haveing taken the premises into our consideration, of our especiall grace certaine knowledge and meere mocon have thought fitt to erect and found and by these presents for Us and Our Successors do erect and found a Colledge in our said City of Durham in Our County of Durham within the scite of the Colledge Houses Cathedral Church and Castle in our said Citty of Durham or some of them To be and continue a Colledge from time to time hereafter forever, and that the same Colledge shall consist of one Provost or Master, two Preachers or Senior Fellows, and twelve other Fellows, fower of the said Fellowes to be Professors fower other of them to be Tutors and other fower of them to be Schoolmasters. And alsoe twenty-fower Schollars twelve Exhibiconers in the said Colledge and eighteene Schollars in the Free School belonging to the said Colledge. And Wee doe by these presents for Us and Our Successors will ordain constitute and appoint that they and their successors shall from henceforth stand and be Incorporated and founded in Name and in Deede One Body Pollitique and Corporate to all intents and purposes and shalbe eligible and be elected as hereafter is declared and shall forever hereafter be called by the Name of the Master or Provost Fellows and Schollars of the Colledge in Durham and of the foundation of Oliver Lord Protector of the Commonwealth of England, Scotland, and Ireland and the Dominions thereto belonging, and by the same Name shall have perpetuall succession. And to the end that the said Colledge may be at

present furnished and provided with fitting persons for this Work and Service Wee doe for Us and Our Successors constitute and appointe Our wel-beloved Phillip Hunton, M.A., to be the first Provost or Master of the said Colledge and Our wel-beloved William Spinedge and Joseph Hill, M.A., to be the two first preachers or Senior Fellows of the said Colledge and our wel-beloved Thomas Vaughan, M.A., John Kiffler, M.D., Robert Wood, M A., Ezerel Tong, D.D., John Peachil, M.A., Leonard Wastel, Richard Russel, M.A., John Richel, Nathaniell Vincent, M.A., William Corker, John Doughty, M.A., and William Sprigg, to be the first twelve other Fellows of the Colledge. Whereof the said Thomas Vaughan, John Kiffler, Robert Wood and John Peachil shall be the first fower Professors, and the said Ezerel Tong, Richard Russel, John Richel and John Doughty shalbe the first fower Tutors of the said Colledge and the said Nathaniell Vincent, William Corker, William Sprigg and Leonard Wastel, shall be the first fower School Masters of the said Colledge. And Wee doe by these presents for Us and Our Successors with the advice of Our Council of Our like especiall Grace certaine knowledge and meere mocon and for the endowment of the said Colledge with some competent meanes for the maintenance thereof and for the better advancement of Learning and Religion in those parts, Give and Grant unto the Master or Provost Fellows and Schollars of the said Colledge in Durham of the Foundacon of Oliver Lord Protector of the Commonwealth of England, Scotland, and Ireland, and the dominions thereto belonging and their successors all that the Cathedrall Church and Churchyard and Colledge of Durham aforesaid and alsoe all and singular messuages and houses and all orchards, gardens, courts, courtyards, curtileges, wastes and waste grounds hereunto belonging which are yet unsold, and which were lately belonging to the late Dean and Chapter of the said Cathedral Church of Durham, and the Free School there and School Houses, and the Houses for School Masters there, with all Orchards, Gardens, etc., with theire and every of theire rights, members, precincts, priviledges, hereditaments and

appurtenances in any wise unto any the Premisses belonging in as ample manner as the late Bishopp or Dean and Chapter of Durham or the Trustees for Sale of the Lands and Possessions, of the late Bishopps, Deans and Chapters or any of them have held and enjoyed. . . . Also all that yearly rent of £117 15s. 8d. reserved by one Indenture of Lease bearing date on or about the sixth day of April in the twenty-fourth year of the late Queen Elizabeth, made by Richard (Barnes) Bishopp of Durham, etc., payable out of the several manors of Gateside, *alias* Gateshead, and Wickham . . . also one yearly rent charge of £500 per annum out of the aforesaid manors . . . one other yearly rent charge of £282 4s. 4d. payable out of the Rectories impropriations and parsonages impropriations late belonging to the late Bishopp or Dean and Chapter .. . . . Wee also Grant all manuscripts Library books and other books and mathematical instruments and all other instruments whatsoever late belonging, etc., either or any of them respectively relating to the practise of any of the Liberal Sciences. Also give and Grant that it shall be lawful for them from time to time and at all times hereafter to purchase, have and hold any land, tenement, etc, not exceeding the yearly value of £6,000 . . . . We will Ordain and Appoint that the said Colledge by the name of the Master, etc., shall have power and authority to demise lease and grant these possessions. We also Grant to have a common seal and We have nominated Sir Thomas Widdrington Knight, Speaker of the Parliament, and John Lambert, Major General and Commander in Chief within our Counties of York Durham Westmorland Cumberland and Northumberland, and Walter Strickland of our Council, and Algernon, Earl of Northumberland, Thomas, Lord Fairfax, William, Lord Grey of Wark, George, Lord Eure, Philip, Lord Wharton, etc., etc.

Witness Ourselves at Westminster 15 May, 1657.

(Signed) Beale.

[This document is printed in full in Hutchinson's *Durham*, I. pp. 518-527.]

The Development of Mathematics in the Nineteenth Century.

By J. T. Merz, Ph.D., D.C.L.

[Read June 20th, 1903.]

It will be evident to anyone who looks at the treatment of mathematical subjects at the present day and compares it with that of a generation ago, or still more with that of the earlier part of the nineteenth century, that a great change has taken place. But if one attempts to put into definite language what this change consists in, the task is not very easy. There are various ways in which we may go to work if we desire to arrive at an answer.

Perhaps the easiest way would be to select such expressions used in mathematical language as did not exist in earlier text books, or such as have received altered meaning. This would lead to an historical inquiry which would show where and by whom the new terms have first been used and what was the inducement to introduce them. Similarly, we might trace the development of our knowledge or our ideas in any other subject by resorting to a study of the vocabulary of the language employed in each department.

The nineteenth century has probably extended the vocabulary, both scientific and philosophical, in all the principal languages, more than any other preceding period. All the better dictionaries and encyclopedias prove this conclusively: no better example could be given than a comparison between the recent supplementary volumes of the *Encyclopedia Britannica* with those published during the last quarter of the nineteenth century. The result of such a study, even if undertaken only over a very small department, could not fail to be highly instructive, but to do it

with any completeness would be very laborious. For this reason it may be well to look out for some other point of view and some other method in treating of any particular science.

It is only within the last generation that a serious interest has been taken in the history of the various sciences: before that time it would have been almost impossible to name any science in which the modern developments had been exhaustively traced. Historical statements referred usually to special problems or to the work of individuals and were not unfrequently written by men of great eminence, but they were not brought into any connection and were buried in periodical publications or the Reports of Academies. As soon as the necessity was felt for comprehensive histories the great difficulty presented itself in the enormous bulk of special research in every department. A similar difficulty has been met with in the writing of political or literary history, the mass of material is everywhere overwhelming, and except some other point of view can be gained than that of a chronological or biographical record of events or researches history will very soon become impossible. It is therefore fortunate that with the enormous accumulation of material, another process has kept pace which will enable us to gain those more commanding points of view from which a survey is practicable.

So far as the sciences and many other departments of intellectual progress are concerned it has been generally recognized that the purely enumerative method, which limits itself to the statement and registration of facts, does not suffice to ensure progress. Everywhere it has been found necessary to establish leading ideas under the guidance of which special research has had to proceed. This is no less the case in the science of mathematics than in other sciences, be they now concerned with physical, mental or historical facts.

Lagrange deplored at the end of his life the coming generation of mathematicians who would not only have to study the quartos of Euler, Newton and others, but also those of himself, his contemporaries and successors.

He foresaw with alarm the increasing accumulation of material. The nineteenth century has done much to avert the dreaded difficulty by everywhere emphasizing the leading ideas rather than the detailed applications to special problems.

Jacobi already stated that ideas were more important than elaborate calculations.

Simplification and elegance have in many cases removed lengthy and cumbrous formularies, so much so that in reply to the thesis of Eisenstein, viz., that mathematics was not only a science but also an art, an eminent mathematician could reply that mathematics was indeed an art but not a science.

The correspondence between Gauss and Schumachev opens with a demand by the latter that Gauss should compete for a prize which a Portuguese mathematician named Pedrayes had offered for the solution of a certain differential equation and with the characteristic answer of Gauss that he took no interest in the solution of such special problems, but only of such questions as promised to open out new vistas into the higher regions of analysis.

The history of science will accordingly have more and more to limit itself to an attempt to mark prominently the distinct and changing lines of reasoning which exist in every science, leaving the study of manifold applications to special treatises which occupy themselves with restricted departments. It is no doubt in consequence of this necessity that general histories of science have only been written in small number, whereas the histories of the separate sciences have within the last thirty years, been accumulating and still more so the histories of special chapters in the different sciences.

The last comprehensive attempt to write the history of mathematics—that of Professor M. Cantor—had to stop in the middle of the eighteenth century, as it became evident that the history of the modern period could not be written on the same lines as the history before that time, and although Professor Cantor has named several living mathematicians,

who could bring down the work to the present day it is evident that these, on their part, prefer to work up the subject in special reports which are now being published by the German Mathematical Association: in a somewhat more extended form, but similar to that adopted in the Reports of the British Association by several eminent mathematicians in this country in the course of the last seventy years.

The undertaking on which I myself have entered under the title of "A History of European Thought in the Nineteenth Century" purposes to deal with the intellectual history of that period from the point of view explained. Since the publication of the first volume in 1896, the necessity of dealing with the subject in this manner has been evidently felt in many quarters. I instance only a French publication which, under the title of *Bibliothèque de Philosophie Scientifique*, is edited in undated volumes by Dr. Le Bon. The prospectus contains the following characteristic announcement:—"Scientific facts become multiplied to such an extent that it is impossible to know their aggregate. Scholars are obliged to confine themselves to very circumscribed specialities. In spite of incessant discoveries the general principles which direct every science and constitute its philosophical apparatus are never very numerous. They change rarely and cannot change without a complete transformation of the science which they inspire. The profound evolution which the Physical and Natural Sciences have undergone during the last fifty years is the consequence of the change of philosophical principles which supported and directed the labours of those who carried on the research. In order to keep up an acquaintance with scientific philosophical and social knowledge it is necessary to direct our attention mainly to the principles which are the soul of their knowledge and form at the same time its best summary."

Moreover, this altered conception of the duties of the historian and notably of the historian of science, has its justification in another feature of modern intellectual development. When the separate sciences took the place of the one general science called "Philosophy," they inherited also

the aims which characterized the parent science. One of these aims was, so far as the Natural Sciences were concerned, the investigation into the "Nature of Things." This aim is now generally admitted to be hopeless. The "Nature of Things" is unapproachable for the human intellect. This conviction has dawned and gradually settled on the human mind from two separate sides. First, there are the incessant and latterly increasingly frequent changes which have been witnessed in all these sciences which deal with facts and so called truths of Nature. These changes have brought about a general distrust in the finality and reliability of scientific knowledge.

The second influence referred to comes from the side of philosophical criticism which permeates all our thinking since the end of the eighteenth century and has resulted in a settled distrust in the capacity of the human intellect of reaching *Truth* in the older sense of the word. The value of the scientific knowledge of nature is now recognised to lie solely in its practical application Among the sciences, mathematics, however, occupies a unique position. Originally used merely as an instrument to serve practical purposes, the development of modern mathematical science has lain rather in the direction of emancipating mathematical research from the trammels of conventional ideas suggested by practical application.

All the great departures in modern mathematical science have consisted in establishing more general aspects and in using them to develop a more general conception of those methods which former ages had devised for the solution of special problems. Thus we have generalized co-ordinates in the place of the older Cartesians and polar co-ordinates; a more general conception of the space element; we have the idea of space of any number of dimensions—likewise of various geometries in the place of the Euclidean geometry; the idea of different algebras or of an algebra of algebras. Lastly, also of the system of numbers which possess different properties from those possessed by the ordinary integers of arithmetic and, embracing both algebra and geo-

metry, we have the idea put forward by Grassmann of a general arithmetic and algebra of extended quantity. Hardly any of these generalizations were dreamt of in the eighteenth century. A beginning has been made in rewriting the text books of mathematical science on the foundations of definitions which we owe to these and other generalizations.

But the process of generalization involved a danger which was not, to begin with, fully realized. Mathematical conceptions or quantities from which these generalizations had arisen, had been handled by certain methods or operations the correctness of which was either evident or had been established in individual cases by the correctness of the result. When these conceptions were generalized the question arose whether in this generalized form the same operations could be trusted to lead to correct results. It was probably to the numerous paradoxes which presented themselves through their own confident application that the suspicion of critical thinkers was aroused that many of these generalizations were illegitimate.' In consequence a new task presented itself. It became necessary to investigate to what extent well known analytical devices could be applied in full generality, or, if they could not, to define the region of their validity and legitimate use. This undertaking necessitated stricter and wider definitions and an abstract investigation into the nature and logic of mathematical reasoning. In this way mathematical science has acquired a position quite different from that of other sciences, inasmuch as on the one side it prepares the instrument with which all the other sciences work--and on the other side it suggests logical and psychological investigations, which were formerly considered to belong to philosophy *par excellence*. The older school of mathematicians, especially in this country, professed to supply both the logical introduction and the means for practical application. The great model in this respect was the geometry of Euclid or the geometrical treatment of conic sections. In more recent times it has been felt that the two sides which the science presents have grown to such an extent that a division has become necessary.

Out of this conviction which is consciously or unconsciously forcing itself upon mathematicians—especially upon teachers of mathematics—there have arisen two different schools which are termed abroad precision- and approximation-mathematics—the former forming as it were the philosophical groundwork, the latter furnishing the means for the application of the science. And it is a characteristic phenomenon in the history of mathematical thought that the end of the nineteenth century should produce such works as Dr. Perry's "Mathematics for Engineers," and at the same time, in all countries where mathematical science is cultivated a whole array of works which deal with the foundations of the science, its most general conception, and this without any regard for practical application. It seems to be the duty of future science to hand over to the practical mathematicians such definitions and axioms as can be safely employed by him in the solution of practical problems, and on the other side to connect these definitions and axioms in some scheme of consistent logic which will throw great lights upon the principles of abstract reasoning, illuminating in this way processes of human thought which were hidden to the older philosophy or only outlined in the dry formulæ of conventional logic. In this way mathematics will wrest from philosophy another province, and it is sufficiently alarming to future metaphysicians, as it has been to naturalists of the present day, that they will have to become more intimately acquainted with the science of symbolic reasoning. It is also interesting to mark that a literature of this kind has existed in this country since the age of Peacock and de Morgan, from whom, through Boole and Hamilton, it has descended to recent representatives of the Cambridge School—notably Whitehead and Bertrand Russell. In Germany it was mainly Hermann and Robert Grassmann who, for more than twenty years, laboured unknown and unrecognized, till Hermann Hankel published his well-known tract in the year 1867. Since then we have a great literature represented mainly by Georg Cantor and Dedekind on the one side—by Schrœder and Frege on the

other, not to speak of the investigations of Riemann and Helmholtz regarding the foundation of goemetry. In Italy there has also arisen a whole school of mathematicians, headed by Peano; in America we have Peirce, and in France Borel, Couturat and, latterly, Poincaré. We are reminded at the end of the nineteenth century of the inscription over the portals of Plato's Academy: οὐδεὶς ἀγεωμέτρητος εἰσίτω.

It would lead me too far to enter with more detail into the different ideas and abstract problems which the development of mathematics has forced upon the attention of metaphysicians. I will only mention one conception which, in some form or other, lies at the bottom of all the great generalizations on the basis of which the different structures of scientific thought have been raised. It is the idea of Order, which seems to be the simplest form of expressing that postulate without which no scientific knowledge of the phenomena of Nature, *i.e.*, no natural knowledge, is possible. Every attempt to gain such natural knowledge—indeed all scientific thought—takes this postulate for granted.

More than a hundred years ago Hume and Kant put forward this statement under the form of causality. Without this they maintained that connection of ideas in the form of knowledge of external things was impossible. This statement has been repeated through the greater part of the century and endorsed by such an authority as Helmholtz. Latterly this statement has been altered and simplified mainly under the influence of Ernst Mach; it has been reduced to the simpler formula that we must assume the existence of some kind of order. Through this change, the problem of the intelligibility of Nature by the human mind has taken a mathematical form, whereas causality is not a conception accessible to mathematics. At the same time and, as it would appear, under quite independent influence, mathematicians have been induced to study arrangements to such an extent that whereas it was possible formerly to define mathematics as the science of quantity we must now add as equally important the definition as a science of arrangement.

Mathematics in fact, at the end of the nineteenth century has become quite as much a science of tactics as it was formerly a science of quantities.

It is again very largely owing to English mathematicians —notably Cayley and Sylvester, followed by Macmahon, that this has been recognized; the older German school of combinatorial analysis in the beginning of the nineteenth century having left no lasting mark in the development of the science. The great problem that is thus handed over by both science and mathematics to philosophy is the question of Order. "A discussion of Order," says Mr. Bertrand Russell, "which is lacking in the current philosophies has become essential to any understanding of the study of mathematics." And again he says, "What is Order? This is a difficult question and one upon which nothing at all has been written. The discussion is of purely philosophical interest and might be wholly omitted in a mathematical treatment of the subject."

It is the philosophical problem urged by mathematicians and naturalists alike upon the consideration of metaphysicians.

PROCEEDINGS

OF THE

University of Durham Philosophical Society

(Abstracted from the Proceedings).

November 6th, 1902.

(At the College of Science, Professor Bedson in the Chair.)

Prof. Gilchrist, Messrs. Black, Brennan, Duncan, Treble and Witten, and Miss Lebour were elected members.

The following Officers were elected for the session :—

President
The Warden.

Vice-Presidents
Professor Lebour.
Professor Louis.
Dr. Merz.
Professor Potter.
Professor Sampson.
Professor Stroud.

Hon. Secretaries
S. H. Collins.
R. B. Greig.

Editor ·
F. C. Garrett

Section **A** *Chairman*.
J. A. Smythe.

Section **A** *Secretary*.
A. Merrick.

Section **B** *Chairman*:
R. A. Bolam.

Section **B** *Secretary* ·
M. Brack.

Committee:

R. W. W. Bainbridge.	A. Meek.
Professor Jessop.	A. L. Percival.
F. B. Jevons.	W. M. Thornton.

Professor Louis gave an account of a recent visit to Trinidad, illustrated by a number of photographs.

November 21st, 1902.

Chemical and Physical Section.

(At the College of Science, Dr. Merz in the Chair.)

Messrs. J. C. Brown, H. Dobeson, Dixon, J. B. Peat, A. Short, W. H. Sodeau were elected members.

Mr. Collins read a note, illustrated by lantern slides, on the "Electrical Manufacture of Calcium Nitrate."

Mr. Holohan read a note on "Selenium," and exhibited specimens.

December 4th, 1902.

Biological Section.

(At the College of Science, Prof. Potter in the Chair.)

Messrs. R. Ossettich and W. W. Firth were elected members.

Dr. Geo. Potts read a paper on "Dictyostelium Mucoroides."

December 21st, 1902.

Mathematical Section.

(At the College of Science, Prof. Sampson, in the Chair.)

Rules of Procedure were adopted, and the incorporation in the Philosophical Society was agreed to.

Mr. P. J. Heawood read a paper on "Verniers."

Mr. C. J. Van der Heyden described the methods of mathematical study in the University of Goettingen.

February 19th, 1903.

Biological Section.

(At the College of Science, Prof. Potter in the Chair.)

Mr. E. P. Witten read a paper on "The Development of the Crab."

January 22nd, 1903.

(AT THE COLLEGE OF SCIENCE, PROF. STROUD IN THE CHAIR.)

The University of Durham Mathematical Society was incorporated as Section C.

Prof. Potter read a note on "The Decomposition of Oxalic Acid by Plants."

Dr. Thornton read a note on "The Application of Electricity to Growing Plants."

March 5th, 1903.

(AT THE COLLEGE OF SCIENCE, PROF. STROUD IN THE CHAIR.)

The following Rules were adopted :—

NAME.

I.—The Society shall be called the UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

OBJECTS.

II.—The objects of the Society shall be (*a*) the promotion of research, (*b*) the communication and discussion of facts and ideas bearing upon scientific and philosophic questions, (*c*) the exhibition of specimens, apparatus, and books, and (*d*) friendly intercourse between workers in different fields.

MANAGEMENT.

III.—The business of the Society shall be managed by a Committee elected at the meeting in the month of November, consisting of the officers, and six other members of whom three at least shall be re-elected each year. The sectional officers shall be *ex-officio* members of committee.

OFFICERS.

IV.—The officers of the Society shall be a President, six Vice-Presidents, an Editor, and two Secretaries (one of whom shall also act as Treasurer). The President and Vice-Presidents shall be elected annually, but not more than four of the Vice-Presidents shall be re-elected in each year; the Secretaries shall be appointed for two years, but one of them shall retire in each year. All elections shall be by ballot. All officers shall be eligible for re-election.

V.—The officers of each section shall be a Chairman and a Secretary, and shall be elected annually at a meeting of that section. In the event of any section failing to elect its officers before the first general meeting of the Society in each session, the general meeting shall have power to fill the vacancies.

MEMBERSHIP.

VI.—All past and present students in the Colleges of the University, all past and present members of the University, and of the College Staffs and Councils shall be eligible for membership of the Society. Persons not qualified for the ordinary membership of the Society may become Associates. Associates shall enjoy all the privileges of members except that they shall not be eligible to fill any office or to vote. Candidates for election must be nominated in writing by two members of the Society, and their nominations must be in the Secretaries' hands at least three days before the meeting of the Society at which they are to be proposed. Elections shall be by ballot, and a candidate shall not be elected unless at least three-fourths of the votes given are in his or her favour.

MEETINGS.

VII.—The Committee shall decide the place and time of each meeting, but in the course of the year one meeting at least shall be held in Newcastle, and one at least in Durham. It shall be the duty of the Secretaries to send each member a written notice three days before each meeting.

SUBSCRIPTION.

VIII.—Each members shall pay an annual subscription of Five Shillings, or a life subscription of £4. Members whose subscriptions for the current year are unpaid shall not be entitled to receive copies of the Society's Publications, and those whose subscriptions are two years in arrears may be struck off the List of Members by the Treasurer.

VISITORS.

IX.—Members shall have the privilege of introducing friends.

Mr. J. W. Bullerwell was elected Secretary *vice* Mr. Greig, resigned.

Mr. Sodeau read a paper on the "Decomposition of Chlorates," illustrated by experiments.

Prof. Bedson exhibited specimens of palladium, and Mr. Merrick showed the crystallization of potassium chloride from gelatine solution.

March 6th, 1903.

CHEMICAL AND PHYSICAL SECTION.

(AT THE COLLEGE OF SCIENCE, DR. SMYTHE IN THE CHAIR.)

Lord Barnard, Messrs. G. A. Brennan, J. W. H. Harrison, A. O. Langdale, J. MacLaren, K. W. Middleton, R. A. Ritson,

Misses D. E. Birchall, K. Burnett, M. K. Heslop, J. W. Hutty, N. March, and E. E. Wright, were elected members.

Mr. D. Woolacott, read a paper, illustrated by lantern slides, on "The Geological History of the Tyne, Wear, and associated Streams."

May 14th, 1903.

(At University College, the President in the Chair.)

The President read a paper on "Oliver Cromwell's College

June 20th, 1903.

Mathematical Section.

(At the College of Science, Prof. Sampson in the Chair.)

Professor Sampson was elected Chairman, and Professor Jessop, Secretary of the Section; Messrs. Goldsbrough and Thomson were elected members of the Sectional Committee.

The following papers were read :—

"On the Tracing of Caustic Curves," by Mr. A. L. Percival.

"On the Graphical Solution of Quartic Equations," by Mr. G. W. Caunt.

"On Developments of Mathematics during the Nineteenth Century," by Dr. J. T. Merz.

LIST OF MEMBERS OF THE SOCIETY

* *Denotes an original member.*

Adams, Rev. W. R., B.A.
Alexander, F. W.
*Armour, A. L.
Arnison, W. D., M.D.
Ashby, A.S., B.Sc.
*Baker, T., M.Sc.
Bainbridge, R. W. W.
Barnard, Rt. Hon. Lord, D.C.L.
*Bedson, Professor P. P., M.A., D.Sc.
Betts, R. F., B.Sc.
Birchall, Miss D. E., B.Sc.
Black, T. P., M.A., B.Sc.
*Bolam, R. A., M.D.
Brack, Rev. M., B.A., B.Sc.
*Brady, Professor G. S., M.D., LL.D., D.Sc., F.R.S.
Brennan, A.
Brennan, G. A.
Brown, J. C.
Bryant, C. H., M.D.
*Bullerwell, J. W., M.Sc.
Burnett, Miss K.
Cadman, J., B.Sc.
*Cairns, Mrs. C. W., B.Sc.
Cairns, C. W., M.Sc.
*Campbell, William, B.Sc., Ph.D.
*Caunt, G. W., M.A.
Collins, S. H.
Cousins, H. W., B.Sc.
Cullen, H. R., B.A.
*Dale, Sir David, Bart., D.C.L., D.L.
Dixon, —
Dobson, H.
Dodds, Roger.
Dow, C. R., B.Sc.
Dudley, C. R., A.Sc.
Duncan, J. B.
Firth, W. W., M.Sc.
Fletcher, Rev. Mark, M.A.
*Fowler, Rev. J. T., M.A., D.C.L.
Gardner, J. C., B.Sc.
*Garrett, F. C., M.Sc.
Gill, E. Leonard (*Associate Member*).
Gilchrist, Professor D. A., M.Sc.
Godwin, Rev. G. H., M.A.
Goldsbrough, G. R.
*Gravell, John.
*Gray, W. R. H., M.A.
Greig, R. B.
*Gurney, Rev. Principal H. P., M.A., D.C.L.
Gurney, Miss L. M., B.Sc.
Gurney, Miss T. F., B.Sc.
Harrison, J. W. H.
Hatton, R. G.
*Havelock, T. H., M.A., M.Sc.
Hayward, J. W., M.Sc.
*Heawood, P. J., M.A.
Hepple, R. P.
Heslop, Miss M. K.
Hodgkin, T. E.
Holohan, M., B.Sc.
Horsley, S. G., B.Sc.
*Howden, Professor R., M.A., M.B.
Howson, C., B.Sc.
Hunter, T., A.Sc.
Hutty, Miss J. W.
*Jessop, Professor C. M., M.A.
*Jevons, F. B., M.A., D.Litt.
*Kitchin, The Very Rev. Dean, M.A., D.D.

Langdale, A. O.
Laws, A. R.
*Lebour, Professor G. A., M.A., M.Sc.
Lebour, Miss M. V
*Linton, A., B.Sc
Lord, Professor W Frewen, M.A.
*Louis, Professor Henry, M.A., A.R.S.M.
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*Patterson, R. J., M.Sc.
Pearce, Rev. R. J., M.A., D.D.
*Peacock, Miss M. I., A.Sc.
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*Percival, A. L., M.D.
*Philipson, Professor Sir G. H., M.A., M.D., D.C.L.
Philipson, W., A.Sc.
*Plummer, Rev. A., M.A., D.D.
*Potter, Professor M. C., M A.
Potts, G., B Sc., Ph.D.
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Richardson, G. W., M.D.
Richardson, Miss.
Ridley, Miss E. L. R. M., A.Sc.
Ritson, R. A.
Robson, R., B Sc.
Rollin, C., B.Sc.
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Short, A., B.Sc
Simpson, H. H., B Sc
Smith, S. P.
Smythe, J. A., Ph.D., M.Sc.
Sodeau, W. H.
Stock, C. H. J.
*Stroud, Professor Henry, M.A., D.Sc.
Tate, A. E., B.Sc.
Temperley, Miss, M.A.
Thomson, G. H., B.Sc.
Thomson, W., M.A.
Thornton, W. M., D.Sc
*Todd, J. J, A.Sc
Treble, R. L., B.Sc.
*Urwick, W. E., M.A.
Van der Heyden, C. J.
*Wade, Thomas.
Watt, H. E., M.Sc.
*Watson, F. B., M.A., M.Sc.
Welford, R., M.A.
Widdas, P.
Wilcox, F A., B.Sc.
Witten, E. P.
Woolacott, David, M.Sc.
Wright, Prof. Mark R., M.A.
Wright, Miss E. E.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY

Balance Sheet for Session 1902-1903.

Income.	£	s.	d.	Expenditure.	£	s.	d.
To Balance from Session 1901-1902	17	14	5½	By Printing and Issuing Notices of Meetings	5	10	11
,, 1 Subscription, 1900-1901	0	5	0	,, Printing *Proceedings*	8	12	0
,, 8 Subscriptions, 1901-1902	2	0	0	,, Expenses of holding Meetings	3	17	6
,, 72 ,, 1902-1903	18	0	0	,, Secretarial Expenses	2	4	6½
,, Sale of *Proceedings*	0	6	6	,, Assistant Treasurer's Commission	0	10	0
				,, Balance in Treasurer's hands	17	11	0
	£38	5	11½		£38	5	11½

Examined and found correct;

HENRY LOUIS, *Auditor.*

October 15th, 1903.

UNIVERSITY OF DURHAM
PHILOSOPHICAL SOCIETY.

A NOTE ON MOLYBDENUM.

By JOHN COGGIN BROWN, B.Sc.

[Read December 10th, 1908.]

Molybdenum is a metal of the sixth group, being associated therein with the elements chromium, tungsten, and uranium. It is usually found as molybdenite (MoS_2), a mineral belonging to the hexagonal system occurring—generally with copper pyrites, in the granite of Shap Fells, and in many Cornish mines—in massive pieces which possess a very perfect cleavage, and split up indefinitely into thin, sectile and almost malleable laminæ; its colour is identical with that of graphite, from which it is distinguished by its slightly greenish streak. Molybdenum is also found in the form of molybdates, notably as wulfenite or lead molybdate ($PbMoO_4$), many iron ores contain traces of it, and so it is sometimes found in minute quantities in pig iron and in slags.

Molybdenum compounds are best prepared from the native sulphide by oxidation in the air at high temperatures, the trioxide so formed being a convenient starting point for other compounds. By heating the mineral to redness in a hard glass tube and slowly aspiring air over it oxidation takes place, and the trioxide sublimes in clear tabular crystals. Another method which gives results more quickly, is to powder the mineral as finely as possible, mix it with its own weight of sand, and strongly heat on an iron plate for three days, turning the material every hour; in this way the molybdenite is partially oxidised.

The washed product is now boiled with dilute ammonia, which dissolves the molybdenum trioxide, at the same time precipitating

any iron salts which may be present; after filtering off from sand and unaltered molybdenite, two or three drops of ammonium sulphide are added to the filtrate to precipitate copper salts which are usually present in small proportions The liquid is now filtered again and concentrated by evaporation, when nitric acid is added, which precipitates the trioxide (MoO_3), which is filtered off, well washed and dried. It can be further purified by redissolving in ammonia, crystallizing out the molybdate so produced and decomposing this again with concentrated nitric acid.

Molybdenum trioxide (MoO_3) is a white impalpable powder which turns yellow on heating, it sublimes in the air in colourless transparent rhombic tablets, and is slightly soluble in water, to which it imparts weak acidic properties. This oxide corresponds to chromium trioxide and forms molybdates analogous to the chromates.

Molybdenum dioxide (MoO_2) is prepared by reducing the trioxide in hydrogen, it is a black powder and forms the unstable molybdenum salts.

The halogen compounds are numerous, each oxide having several corresponding chlorides and bromides. By passing chlorine over heated mixtures of molybdenum trioxide and carbon some of these chlorides and oxychlorides are obtained; they are all green or yellow compounds possessing a pungent smell, and rapidly combine with the moisture of the air, forming blue liquids.

Molybdenum is prepared by the reduction of the trioxide with powdered aluminium, the mixture being placed in a crucible and fired by means of a magnesium powder; any unaltered aluminium being dissolved out with the hydrochloric acid. Pure molybdenum was found to be a very hard, silver white metal, and very infusible; soluble in nitric acid, but not attacked by dilute sulphuric or by hydrochloric acid.

The molybdates are formed by the combination of the acidic molybdenum trioxide with basic oxides, and many complex molybdates can easily be obtained as

Mono-Molybdates ...	$R_2OMoO_3\ xH_2O$	
Di-Molybdates ...	R_2O2MoO_3	
Tri-Molybdates ...	R_2O3MoO_3	etc.,

the proportion of molybdenum steadily increasing up to 16 molecules as in the sodium molybdate $Na_2Mo_{16}O_{49}$. The best-known molybdates are those of ammonium. Ordinary ammonium molybdates has the formula $(NH_4)_6Mo_7O_{24} + 4H_2O$; it crystallizes in six-sided monoclinic prisms.

Lead only forms one molybdate $PbMoO_4$; this is prepared by adding a soluble lead salt to a soluble molybdate and comes down as a heavy white insoluble powder. The easy production and the insolubility of this salt under ordinary circumstances make it very useful as a means of estimating molybdenum.

Calcium, barium and strontium form molybdates in the same way as lead. Nickel, cobalt and manganese form coloured molybdates, the nickel salt being apple green in colour, the cobalt salt mauve, the manganese salt buff. Zinc molybdate is a white solid.

Molybdenum is in the same group as sulphur, to which it should, therefore, show some resemblance, this is seen in the formulæ of the acids H_2SO_4 and H_2MoO_4. Some of the sulphates are isomorphous with the molybdates, and, by mixing solutions of ammonium molybdates and magnesium sulphate, a double sulphate is obtained, in which part of the sulphur is replaced by molybdenum without any essential alteration in the crystalline form of the ordinary double sulphate $Mg(NH_4)_2(SO_4)_2 + 6H_2O$. One specimen so prepared contained 14 per cent. of molybdenum.

Molybdenum forms two compounds with sulphur, the disulphide (MoS_2), found native as molybdenite, and the trisulphide (MoS_3), which is formed when hydrogen sulphide is passed into the concentrated solution of a molybdate and an acid added. It is a chocolate-coloured powder difficult to prepare free from sulphur, as it easily passes into the disulphide. It has the power of combining with basic sulphides to form thio molybdates in exactly the same way as the trioxide forms molybdates.

A Sketch of the History of Fourier Series.

By A. F. van der Heyden, M.A.

[Read December 12th, 1903.]

1. The extreme importance of Fourier's Theorem in Mathematical Physics is of itself sufficient to make the story of its development of interest to all students of mathematics. The fact that a thorough insight into its history can only be acquired by considering the development of the treatment of infinite series and of the idea expressed by the word "function" makes this story worthy of special study.

We shall, accordingly, commence by pointing out the most important steps in the growth of the theory of infinite series and of the signification of the word "function."

2. The introduction of infinite processes was, in the first instance, brought about by the desire to effect the quadrature of the conic sections. Thus Archimedes* (200 B.C.) found the area cut off by a chord of a parabola by what amounted to the use of the series

$$1+\frac{1}{4}+\frac{1}{4^2}+\ \ldots$$

Similar problems were discussed in the seventeenth century by Cavalieri, Fermat, Pascal, Wallis and others.

As early as 1665, Newton had discovered the binomial series, though he did not publish his results till many years later. In the catalogue of the Portsmouth Papers (p. xviii.) he says :—"In the beginning of the year 1665 I found the method of approximating Series and the Rule for reducing any dignity of any Binomial into such a series."

In 1668, Lord Brouncker published an article† on the Squaring of the Hyperbola. In this he found the area enclosed between one

* Archimedes, *Opera omnia*, ed. J. L. Heiberg, pp. 334, 348, §§ 17, 24.

† "The Squaring of the Hyperbola, by an infinite series of rational numbers, together with its Demonstration."

asymptote of the rectangular hyperbola $xy = 1$, the ordinates for $x = 1$, $x = 2$ and the curve, expressing this area in the form

$$\frac{1}{1.2} + \frac{1}{3.4} + \frac{1}{5.6} + \quad . \quad . \quad .$$

The most noteworthy point is the fact that he considered the convergency of the series.

In the same year Nicolaus Mercator published his *Logarithmotechnia*, in which he gives the result

$$\frac{1}{1+a} = 1 - a + a^2 - a^3 + \quad . \quad . \quad . \quad ,$$

deriving therefrom, for the area contained between the hyperbola $y = \frac{1}{1+a}$ $[x = 1 + a]$, the expression

$$a - \frac{a^2}{2} + \frac{a^3}{3} - \frac{a^4}{4} + \quad . \quad . \quad . \quad ,$$

which is, of course, the logarithmic series.

The use of infinite series was extended to a wonderful degree by Newton and Leibniz, and it is again noteworthy that they and their immediate successors felt the need for considering the convergency of the series used. Thus, in one of his letters, Leibniz remarked* (A.D. 1713):—"I could wish that Newton, who was particularly well versed in the theory of series, had pushed the matter further, especially with regard to a way, which would apply to transcendentals as well as in ordinary cases, of learning whether they converge or not."

3. We now come to a period during which infinite series were freely and regularly used. Apparently all doubts as to the correctness of such methods had been dissipated and non-convergent series were employed just as if they were ordinary quantities, an unconscious process of induction leading to the idea that they would all obey the ordinary laws of algebra.

An amusing piece of reasoning is quoted by Reiff† in this connection. Having observed that

$$\frac{1}{1+x} = 1 - x + x^2 - x^3 + \quad . \quad . \quad . \quad ,$$

* Leibniz, *Math. Werke*, ed. Gerhardt, III., p. 922.

† Reiff, *Geschichte der Unend. Reihen*, pp. 65-66.

a monk, named Guido Grandi (A.D. 1710), put $x = 1$, obtaining the result

$$\tfrac{1}{2} = 1 - 1 + 1 - 1 + \quad . \quad . \quad . \quad . \qquad ad\ inf.$$

In justification of this result he supposed that two brothers inherited a priceless gem from their father on condition that it was not to be sold. They accordingly decided to hold it for one year each in turn. This being done by themselves and their descendants for ever, it followed that each family gave and received the gem an infinite number of times, whilst each held the stone for one half of the time. He also deduced that

$$\begin{aligned}\tfrac{1}{2} &= (1-1) + (1-1) + \quad . \quad . \quad . \quad . \\ &= 0 + 0 + \quad . \quad . \quad . \quad .\end{aligned}$$

and thence decided that it was possible for the world to have been created out of nothing.

Varignon was the only mathematician, at this time (A.D. 1715), to protest against the use of such series.* He maintained that no series should be used unless its terms continually diminished in such a way that the remainder could be neglected.

Euler, who contributed most to the theory, held very loose views. They are exemplified in a correspondence with Nicolaus Bernoulli, who objected to the use of series whose terms were ultimately infinite, pointing out that, by their means, the same quantity would be represented by totally different expansions. Thus

$$\frac{1}{1-1-1} = 1 + 1 + 2 + 3 + 5 + 8 + 13 + \quad . \quad = -1,$$

and $$\frac{1}{1-2} = 1 + 2 + 4 + 8 + 16 + \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad = -1.$$

Euler replied (A.D. 1745) by saying that the equivalent did not denote a summation but the possibility of developing the expression in a series.†

4. We now pass on to a period of criticism, in which the results obtained by Euler and others were subjected to a careful scrutiny. Criteria of the convergency of series were formulated and, with some misgivings at first, divergent series were rejected as useless to the mathematician.

* Reiff, p. 70. † Reiff, pp, 122-123.

Thus D'Alembert (A.D. 1768) remarks* :—"For my part, I admit that all reasonings and all calculations based upon series which are not convergent, or which cannot be supposed convergent, appear very suspicious, even when the results agree with facts otherwise established."

Again, in his Theory of Functions (A.D. 1796), Lagrange observes :—"The perfection of the methods of approximation in which series are used does not only depend on their convergence, but also on the estimation of the error due to the terms neglected."†

It is to Cauchy and Abel, however, that we owe most with regard to the adoption of proper views. Cauchy writes (A.D. 1821): —"I am *compelled* to admit several propositions which will perhaps *seem rather strict;* for example, that a divergent series has no sum."‡

In a letter to Holmboë, dated January 16th, 1826, Abel makes the following remarks :—"Divergent series are, in general, very fatal and it is a disgrace that anyone should dare to found a proof upon them. The most essential part of mathematics is without foundation. It is true that the results are *for the most part correct, but that is very strange. I am seeking for the reason of this*—a very interesting problem."§

5. The successive attitudes taken up by the majority of writers, in the three periods referred to, may be respectively characterised by the following three questions :—

(i.) Dare we use an infinite series?

(ii.) What examples of infinite series can we derive from given expressions?

(iii.) Which of these series is it lawful to use?

The final view, characteristic of the present time, is rather :—

(iv.) Under what circumstances can we regard a given infinite series as representing a function :—

Cauchy observed‖ that the convergence of the series $\Sigma(-1)^n\dfrac{1}{n+1}$ depended on the order of the terms, and Dirichlet

* *Opuscules Math.*, v., p. 183.

† *Théorie des fonctions*, § 58.

‡ *Analyse Algébrique*, Preface.

§ Borel, *Séries Divergentes*, p. 11.

‖ *Résum. anal.*, p. 57.

pointed out* that by certain changes the sum of the series was altered, although it remained finite. Riemann shewed† that this was always the case with series which were not absolutely convergent, thus finally establishing the distinction between absolutely and semi-convergent (conditionally convergent) series (A.D. 1867).

The fact that the sum of a convergent series of continuous functions could itself have discontinuities led to the distinction made between uniform and non-uniform convergence. This was discovered by Stokes‡ (A.D 1847) and also, independently, by Seidel§ (A.D. 1848).

Finally, and in this connection we would refer to the italicized portions of the remarks of Cauchy and Abel quoted above, a legitimate use was found for a certain class of divergent series.‖ Two memoirs on the subject appeared simultaneously (A.D. 1886), the one, due to Stieltjes,¶ the other to Poincare,** the latter writer giving the series the name of "asymptotic expansions."

The results of this classification of series may be summarised as follows :—

(1) *Absolutely* convergent series may be multiplied and rearranged.

(2) *Semi*-convergent series may, under certain conditions, be multiplied but cannot be rearranged.

(3) *Uniformly* convergent series are continuous and may be integrated term by term.

(4) *Asymptotic* expansions may be added, subtracted, multiplied, divided (if the divisor possesses an absolute term) or integrated term by term, the result being the asymptotic expansion of the function found by performing the corresponding operations on the given function.

* *Berl. Abhand.*, 1837, p. 48. † *Gött. Abh.*, p. 13.

‡ *Math. and Physical Papers*, I., p. 236.

§ *Abh. der München. Acad.*, VII.

‖ *See* Borel, *Leçons sur les séries divergentes*. Paris, 1901.

¶ "Recherches sur quelques séries semi-convergentes," *Annales de l'Ecole normale*, 1886.

** *Acta Mathematica*, Vol. VIII.

6. The idea of functionality took its rise from Co-ordinate Geometry. Leibniz (A.D. 1692) used the word "function" to denote such lengths as the ordinate, tangent, radius of curvature, etc., which bore a definite relation to the position of a point on a curve.*

The word was used by Joh. Bernoulli to denote a quantity involving a variable and any constants, and Euler† defined a function of a variable as any analytical expression formed of the variable and constants. He also extended the term to include implicit functions and classified them as algebraic or transcendental and also as single-valued or multiple-valued. The discussion of the problem of vibrating cords led him to introduce the idea of "arbitrary" functions, represented by a curve drawn at random in the xy — plane."‡

7. Euler's definition was on the one hand widened and on the other hand narrowed, in consequence of the discovery by Fourier, Dirichlet and others that any arbitrary function could be represented by an analytical expression. The most general meaning of the word is that assigned to it in Dirichlet's definition, viz :— y is a single-valued function of x in the interval (a, b) if a definite value of y corresponds to every value of x, where $a \leq x \leq b$.

It will be observed that the characteristics of a function thus defined might be totally different in one interval from those of the same function in another interval. It was known that two series, convergent in different intervals, might represent the same function in those intervals, but a general mode of considering such facts was not forthcoming. This was accomplished by the consideration of functions of a complex variable, combined with the inevitable restriction of the meaning of the word function. The general conception involved in Dirichlet's definition was retained, but the attention of mathematicians was principally directed to the consideration of "analytic" functions, which were *differentiable* (Cauchy§ and Riemann) or, an equivalent restriction, capable of being represented by a power-series (Weierstrass).

* *Enc. d. math. Wissensch*, II., A1, § 1.

† *Introductio in analysin infinitorum*, Cap. I., § 4.

‡ *Berl. Mém.*, année 1748, p. 69.

§ See *Enc. d. math. Wissenschaften*, II., AI., § 3, Note 34.

8. We are now in a position to grasp the meaning of such a statement as "The series represents the function in the interval (a, b)."

Series were originally used to obtain approximations to the values of functions. This led to the consideration of the convergency of series and then to the enquiry into the nature of the correspondence between the two.

Thus, if two functions can be developed in absolutely convergent series, we may add the series and equate the result to the sum of the functions; we may multiply the series and equate the result to the product of the functions. If one function can be developed in an absolutely convergent series, another in a semi convergent one, we can multiply the series and equate the result to the product of the functions. If a function can be developed in a uniformly convergent series, we can integrate the series term by term and equate the result to the corresponding integral of the function, and so on.

Finally, some or all of these properties may be possessed by a function and a series in a given interval only, with the possible exception of isolated points of that interval. We can then proceed as before, for values included in that interval, with the exception of the singular points referred to, if such points exist.

We shall now endeavour to trace the elucidation of the problem of representing an arbitrary function of a real variable by means of a series of sines and cosines of multiples of the variable.

9. It was Euler who first expanded a rational function in a series of sines and cosines of multiples of its argument. In a paper* entitled "Subsidium calculi sinuum," he proved that

$$\frac{\phi}{2} = \sin\phi - \tfrac{1}{2}\sin 2\phi + \tfrac{1}{3}\sin 3\phi - \ \ . \ \ . \ \ .$$

and thence that

$$\frac{\pi^2}{12} - \frac{\phi^2}{4} = \cos\phi - \tfrac{1}{4}\cos 2\phi + \tfrac{1}{9}\cos 3\phi - \ \ . \ \ . \ \ .$$

At this time the meaning of the word function was restricted to those which could be represented by one curve and it was not

* *Novi Comm. Petrop.*, V., 1754 A.D. (Reiff, p. 127).

realized that one and the same analytical expression could represent one simple function in one interval and quite another function in another interval.

As so often happens, the necessary stimulus for the extension of this conception of pure mathematics came from the study of physics. D'Alembert showed* that the ordinate and abscissa of a vibrating cord, of uniform material and under a constant tension, were connected by the differential equation

$$\mu \frac{d^2y}{dt^2} = T \frac{d^2y}{dx^2},$$

where t denoted the time, μ the mass per unit length, T the tension, the origin being at one end of the cord and the axis of x along its direction when at rest.

He deduced the integral relation

$$y = \phi (x + at) + \psi (x - at) \qquad \left[a^2 = \frac{T}{\mu}\right]$$

but supposed the curve at any instant to be regular.

Euler pointed out† that the solution demanded a more general interpretation of the arbitrary functional symbols ϕ, ψ, thereby extending his definition of a function ‡

Attacking the same problem from a different point of view, Daniel Bernoulli gave§ as the general solution

$$y = a \sin \frac{\pi x}{l} \cos \frac{\pi t}{l} + \beta \frac{\sin 2\pi x}{l} \cos \frac{2\pi t}{l} + \quad . \quad . \quad . \quad .$$

The mathematicians of the period were accordingly compelled to decide between to possibilities, viz.:—

(i.) One of the above solutions might be included in the other, as a particular case, or

(ii.) An absolutely arbitrary function could be represented by a trigonometrical series.

Owing to the narrow conception of functions then prevailing, the general view was in favour of the former supposition, as the more likely one. In 1766, Lagrange shewed‖ that the locus given by the equation

$$y = a_1 \sin x + a_2 \sin 2 x + \quad . \quad . \quad . \quad + a_n \sin nx$$

* *Hist. de l'Acad. de Berlin*, ann. 1747. † *Ibid.*, ann. 1748

‡ Section 6. § Reiff, p. 125. ‖ Lagrange, *Œuvres*, I., p. 551.

could, by a proper choice of coefficients, be made to pass through the n vertices of a broken line and that, by increasing the number n, it was possible to approximate more and more closely to a given curve, a method employed later in obtaining Fourier series.* In the following year Euler published a method of finding the coefficients by means of multiplication and definite integrals.

It was Fourier, however, who not only gave the coefficients but was also the first to shew the real significance of the theorem and to extend the term function so as to include expressions whose graphs consisted of detached pieces of the graphs of various simple functions.†

He gave‡ a proof, on correct lines though incomplete, of the following theorem :—If, in the series $\Sigma\ (a_k \sin kx + b_k \cos kx)$, we have $b_0 = \frac{1}{2\pi} \int_{-\pi}^{+\pi} f(a)\, da$: $b_k = \frac{1}{\pi} \int_{-\pi}^{+\pi} f(a) \cos ka\, da$:

$a_k = \frac{1}{\pi} \int_{-\pi}^{+\pi} f(a) \sin ka\, da$, the series represents the function $f(x)$ for every value of x in the interval from $-\pi$ to $+\pi$. This is the theorem known as Fourier's Theorem and such series are called Fourier Series.

10. This result having been established, the question arose as to whether the theorem were always true, or, if not, what restrictions were necessary to ensure the convergence of the series.§

Feeling the necessity for a rigorous discussion of the theorem, Cauchy furnished a proof, which appeared‖ in 1826, but serious objections were raised against it by Dirichlet and Riemann and it cannot be regarded as satisfactory.¶ Another proof, due to him, appeared in the following year and may be seen, with modifications

* Riemann, *Vorlesungen über partielle Differential-gleichungen.*

† Section 7.

‡ Communicated to the Parisian Academy in 1807, 1811. Théorie de la chaleur, 1822.

§ Cp. section 5 (iii.)

‖ *Mém. de l'Inst.*, VI.

¶ Gibson, "On the History of Fourier Series." *Proc. of the Edin. Math. Soc.*, vol. XI.

and improvements, in Whittaker's *Modern Analysis* (pp. 182-186). The first sound treatment of the subject was that of Dirichlet, who proved* that the theorem was correct for a certain class of functions. His proof is given by Whittaker and his results were as follows :—

The Fourier series for a function converges towards the value of the function at all points excepting those at which the function is discontinuous and, at such points, the series converges to the mean of the two values of the function at either side of the point of discontinuity, provided that

(i.) The function never becomes infinite.

(ii.) The function has not an infinite number of discontinuities.

(iii.) The function has not an infinite number of maxima and minima.

These conditions—"Dirichlet's conditions"—are sufficient, but not necessary, so that we may look for some narrowing of the restrictions thus imposed.

Dirichlet himself, in another paper,† considered the possibility of removing the first, arriving at the result :—

(*a*) If $f(x)$ becomes infinite for $x = c$, the series will still represent the function, provided that the integral

$$\int_{c-\epsilon}^{c+\epsilon} f(a)\,da$$

is convergent.

He also stated that, with certain limitations, it was possible to remove the other restrictions, but never carried out his intention of proving this.

The task of removing, as far as possible, these remaining limitations was taken up by Lipschitz. In a paper,‡ entitled *De explicatione per series trigonometricas instituenda functionum unius variabilis arbitrarium, etc.*, he first proved a result stated by Dirichlet, namely :—

* Crelle, IV., Sur la convergence des séries trigonométriques, etc., A.D. 1829.

† Crelle, XVII., p. 54.

‡ Crelle, LXIII., p. 296.

(*b*) If $f(x)$ have an infinite number of discontinuities in the interval from π to $+\pi$, the series will still represent the function provided that, if a and b lie between $-\pi$ and $+\pi$, it is always possible to insert quantities r and s between a and b such that the function is continuous in the interval (r, s).

He then went on to consider the third of Dirichlet's conditions, relating to functions having an infinite number of maxima and minima in the interval $(-\pi, +\pi)$. This may happen in three ways:

(i.) We may be able to insert between a and b (the limits of the interval considered) two quantities $r-\delta$ and $r+\delta$, such that the number of maxima and minima of the function $f(x)$ between a and $r-\delta$ may be finite, the number between $r+\delta$ and b finite, but the number between $r-\delta$ and $r+\delta$ infinite, where δ is a finite positive quantity which may, however, be diminished at will.

(ii.) It may be impossible to place a finite interval (r, s) within the interval (a, b) such as to contain only a *finite* number of maxima and minima of $f(x)$.

(iii.) The interval (a, b) may contain a finite number of finite parts in each of which one or the other of the above irregularities may occur.

In the first case we say that $f(x)$ oscillates for $x=r$, in the second that it oscillates in the interval (a, b) and in the third that it oscillates for single values of x as well as for finite intervals.

Dirichlet's proof of Fourier's Theorem depended on the following lemma :—

Let g and h be quantities fulfilling the conditions

$$o \leqq g < h \leqq \frac{\pi}{2}.$$

Let the function $f(\beta)$ be finite and continuous from the value $\beta=g$ to the value $\beta=h$ and let it be so constituted that it either continually increases or remains constant throughout the interval or that it continually decreases or remains constant throughout the interval.

Then the integral $\int\limits_{g} f(\beta)\frac{\sin k\beta}{\sin\beta}\,d\beta$ approaches a certain definite value as the quantity k increases without limit and this value is zero if g is positive but $\frac{\pi}{2}f(o)$ if g is zero.

It is plain that, in the case of a function possessing an infinite number of maxima and minima, this lemma is inadequate. Lipschitz accordingly proved (*loc. cit.*) the following more general result :—

Let the quantities g and h satisfy the conditions

$$o \leqq g < h \leqq \frac{\pi}{2}.$$

Let the function $f(\beta)$ be of such a nature that, throughout the interval (g, h), it keeps a value between the values of some constant taken both positively and negatively, and that the difference

$$f(g+\delta) - f(g)$$

becomes as small as we please as the positive quantity δ diminishes and that the difference

$$f(\beta+\delta) - f(\beta),$$

where $g < \beta < h$, approaches a value (as δ diminishes) less in absolute magnitude than any positive power of δ multiplied by another constant. Then, as the quantity k increases without limit, the integral $\int_{g}^{h} f(\beta)\frac{\sin k\beta}{\sin\beta}\,d\beta$ approximates to a definite value. If g is positive, this value is zero. If g is zero, this value is $\frac{\pi}{2}f(o)$.

By aid of this theorem Lipschitz partly removed the restriction implied in Dirichlet's third condition. Thus we have

(*c*) If the function $f(x)$ has an infinite number of maxima and minima, it may still be represented by a Fourier series, provided that, at a point of oscillation β,

$$|f(\beta+\delta) - f(\beta)| < c\delta^{a} \text{ where } a \text{ is positive and } c \text{ a constant.}$$

It should be mentioned that this condition is included in one given by Dini,* viz.:—

$$\underset{\delta = o}{Lt} \, | f(\beta + \delta) - f(\beta) | \log \delta = o.$$

11. We now *turn naturally to the consideration of the nature of the convergence of Fourier series.* In the first place, it is easy to furnish examples of semi-convergent series and of absolutely convergent ones, of non-uniformly convergent series as well as of uniformly convergent series. In that chapter of his *Modern Analysis* which treats of Fourier series, Whittaker arrives at the result:

"If a Fourier series is absolutely convergent for all real values of z, the function represented by the series has no discontinuities and has the same value at $z = o$ as at $z = \pi$.

If these conditions are satisfied, the Fourier series is not only absolutely but is also uniformly convergent."

I have not been able to follow the proof of these statements,† and it would appear that they are at variance with a result of Du Bois-Reymond's,‡ viz., that there are continuous functions of x, the series for which do not converge for special values of x, but I have not seen the paper in which this result is obtained. The question as to the uniformity of the convergence of Fourier series was discussed by Heine,§ who proved that the Fourier series for a finite function $f(x)$, which has only a finite number of maxima and minima, is uniformly convergent if $f(x)$ is continuous from $-\pi$ to $+\pi$ (inclusive) and if $f(\pi) = f(-\pi)$. In all other cases, it is only uniformly convergent *in general*, *i.e.*, with the exception of a finite number of points.

A satisfactory proof of this theorem was given‖ by Gibson, the method being founded upon proofs due to Heine and to Neumann and depending on the "Second Theorem of mean value."

12. In his famous *Habilitationsschrift*, Riemann undertook to prove that it was only possible to expand a function in a series of sines and cosines of integral multiples of its argument in one way.

* "Essai Historique sur la représentation d'une fonction arbitraire par une série trigonométrique," Sachse, p. 22.

† See also *Mathematical Gazette*, May, 1908, p. 292. ‡ Gibson, p. 164.

§ Crelle, LXXI. (1870). ‖ *Proceedings of the Edin. Math. Society*, XII.

His proof involved the integration of a series term by term, a fact which probably induced Heine to consider the uniformity of the convergence of the series.

Having settled this point, Heine proceeded to put Riemann's result upon a proper basis. With this object in view he proved* the following result:—If a Fourier series is, in general, uniformly convergent from $x = -\pi$ to $x = +\pi$ and, in general, represents zero, being certainly finite for all values of x, then all the coefficients must vanish, so that it must always represent zero.

The words "in general" imply that there are to be only a *finite* number of exceptional points.

Cantor had proved that, if two Fourier series were convergent and had the same sum for all but a possible *finite* number of values of x, their coefficients were respectively equal. He afterwards extended† this result to include the following case.

Consider an infinite assemblage (P) of points in a straight line. There will be at least one point in the line such that an infinite number of points of the assemblage P lie in any interval containing it. Let there be an infinite number of such limiting points, forming a second assemblage P^1, which is described as of the *first* order.

An assemblage consisting of an infinite number of limiting points of P^1 is then described as one of the *second* order.

Forming, in this way an assemblage of the *νth* order, we observe that, if ν be an arbitrarily great number, this assemblage must enclose an interval (α, β) containing no point of the assemblage

Cantor succeeded in shewing that if there were an infinite number of exceptional points, in the theorem stated above, forming such an assemblage of the *νth* order (ν arbitrarily great), then the said theorem would still be true.

18. It is now necessary to consider briefly the meaning of the statement that the series *represents* the function. In the first place there seems to be no satisfactory *general* result regarding the absolute convergence of Fourier series, so that this must be considered in each special case before using a Fourier series to represent a junction in operations depending upon the properties of absolutely convergent series.

* Crelle, LXXI. (1870). † *Math. Annalen*, V. (1872).

The labours of Heine and others have determined, as we have seen, the conditions under which such series can be integrated term by term when regarded as representing the function from which they were derived, and Gibson, in his paper on the Uniform Convergence of Fourier Series (A.D. 1893), shewed that they might be differentiated term by term, provided that

(i.) $f'(x)$ obeyed the same conditions as $f(x)$

and (ii.) $f(x)$ was continuous throughout

and (iii.) $f(-\pi)$ was equal to $f(+\pi)$.

Dirichlet proved that, at a point of discontinuity, the series represented the mean value of the function. This led to a very interesting discussion, brought about by the publication of some results of great interest furnished by Du Bois-Reymond. If a Fourier series is discontinuous for $x = x_1$, there is no question but that, when x assumes the value x_1, the value of the series is $\frac{1}{2}\{f(x_1 - o) + f(x_1 + o)\}$. We may however consider the sum of a finite number of terms, say $\phi(x, n)$, and then we may, if we please, generalize the idea of the value of the series, when n becomes infinite, at the point of discontinuity $x = x_1$. This does not contradict Dirichlet's result, but simply raises the question of the advisability of such a generalisation. This can only be settled by the production of some problem of interest in the solution of which such a generalisation would be helpful. Assuming such advisability, Du Bois-Reymond shewed* that the limit of the sum of n terms of the Fourier series, at a point of discontinuity x_1, could be expressed in the form

$$\frac{\pi}{2}\{f(x_1+o)+f(x_1-o)\}-\{f(x_1+o)-f(x_1-o)\}\,Lt\int_o^{h(x_1-x)}\frac{\sin a}{a}\,da,$$

the limit to be taken when $h = \infty$ and $x_1 - x = o$.

If in this formula we first put $x = x_1$, we get Dirichlet's mean value, if we first make n infinite and then put $x = x_1$, we get one or other of the values of the function on either side of the discontinuity, according as x approaches x_1 from greater or smaller values. If, however, we permit these changes to take place together we can obtain all intermediate values.

* *Matt. Annalen*, VII.

That this result is of interest, no one can deny. At the same time the use of a double limit in this manner is very liable to lead to misconceptions and it is unfortunate that, in replying to Sachse's criticisms (contained in the essay already referred to), Du Bois-Reymond practically contradicted himself. In one place he says,* "The trigonometrical series assumes, as is well known, the mean value of the neighbouring values of the function at a point of discontinuity." In another he observes,† "(This formula) must be regarded as the proper determination of the value of the Fourier series at points of discontinuity."

The correct attitude would seem to be that regarding the Fourier series, as such, from the point of view of Dirichlet, reserving the right to use Du Bois-Reymond's result for the double limit of the sum of n terms, when n becomes infinite, at a point of discontinuity, if any problem required such use of a series (in the first instance finite).

In the same paper, this writer gives a corresponding generalisation of the meaning of a differential coefficient at a point of discontinuous curvature.

14. One or two points of some interest have been passed over in silence, partly owing to the limitations of a scanty library, partly owing to the lack of time. In particular, I have been obliged to omit any account of the results given by Du Bois-Reymond in a paper entitled "Ueber den Convergenzgrad der variablen Reihen und den Stetigkeitsgrad der Functionen zweier Argumente," owing to the study of various lengthy treatises which would thereby have been necessitated.

I have been greatly helped by three essays, namely by Reiff's *Geschichte der unendlichen Reihen*, Pringsheim's article "Die Grundlagen der allgemeinen Funktionenlehre" in the famous *Encyklopädie der mathematischen Wissenschaften*, and Sachse's essay on the History of Fourier Series (French translation). The place of the latter would have been filled by Gibson's paper, on the same subject, in the *Proceedings of the Edinburgh Mathematical Society*, if I had had the opportunity of consulting it before my work was nearly finished. The references already given indicate the extent of my indebtedness to other works.

* *Zur Geschichte der Trig. Reihen*, p. 2. † *Zur Geschichte*, etc., p. 19.

Note on Cobaltiferous Mispickel from Sulitjelma, Norway.

By the Rev. Mark Fletcher, M.A., F.G.S.

[Read February 12, 1904.]

Some months ago Professor Henry Louis presented to this college several isolated crystals which he had brought from the Sulitjelma (or Sulitelma) mines in Arctic Norway: they occur there in masses of copper-pyrites and iron-pyrites, for which this district has been famed for some years.

The crystals are of various sizes, ranging in length from 4 to 8 mm. They have a metallic lustre and silver-white colour. The fracture is uneven, and no cleavage is visible. On a freshly broken surface small yellow particles can be seen with the naked eye; these also have a metallic lustre, and are probably iron-pyrites, a probability which is strengthened by the appended chemical analysis. The specific gravity varies from 5·94 to 6·02, and the hardness is just under 5. The crystals are all of a pronounced rhombic aspect. Three of them were measured, and the forms present were found to be {011}, {012}, and {110}; the faces of the forms {011} and {012} are faintly striated parallel to their edges of intersection.

Two of the measured crystals are simple, and the third is a composite growth of two interpenetrant individuals. This latter approximates to a twin, of which the twin-plane is (210); but it is only approximation, the difference between the observed and calculated angles being too large to justify the recognition of a new twin-plane, especially as this relation of the individuals was only found in a single instance.

The means of the best readings of the angles of the simple crystals are the following:—

	Measured.	Calculated.
$(011):(01\bar{1})$	80° 0½′ ..	—
$(011):(012)$	19 16½ ...	19° 12½′
$(012):(0\bar{1}2)$	61 37 ...	61 34
$(110):(1\bar{1}0)$	69 6 ...	—

From the above angles we derive the axial ratios :—

$$a : b : c = 0{\cdot}6886 : 1 : 1{\cdot}1915.$$

These axial ratios suggested that the specimens are crystals of glaucodote; but the following two analyses by Dr. J. A. Smythe, of the Durham College of Science, show that the material is mispickel, containing about one per cent. of cobalt and thus approaching to the variety known as danaite.

	I.	II.	Mean.	Atomic ratios.
S	21·76 ...	21·96 ...	21·86 ...	0·683
As	42·20 ...	42·15 ...	42·18 ...	0·562
Fe	35·31 ...	36·17* ...	35·31 ...	0·632
Co	1·32 ...	0·98 ...	1·15 ...	0·020
	100·59	101·26	100·50	

The atomic ratios show an excess of iron (0·090) and a still greater excess of sulphur (0·121) over that required by the formula (Fe,Co)AsS; this is probably owing to the mechanical intermixture of iron-pyrites, yellow specks of which on the fractured surface are visible to the naked eye.

It remains to be mentioned that crystals of cobaltiferous mispickel (danaite) from Sulitjelma were described by Professor A. W. Stelzner in 1891†: these were a centimetre in length, showed the forms {110}, {011}, {012}, and contained 6·81 per cent. of cobalt.

* Dr. Smythe remarks that in the method adopted in the second analysis there was a risk of insufficient washing, so that the lower figure for the iron is likely to be the more correct.

† A. W. Stelzner, 'Die Sulitjelma-Gruben im nördlichen Norwegen. Nach älteren Berichten und eigenen Beobachtungen besprochen,' Freiberg (Saxony), 1891. Stelzner's results are quoted by J. H. L. Vogt in *Zeits. prakt. Geol.*, 1894, p. 43; and in Hintze's '*Handbuch d. Mineralogie*,' 1901, vol. i., p. 863.

A Note on the Use of Kater's Pendulum.

By Godfrey H. Thomson, B.Sc.

[Read February 12th, 1904.]

In the Kater's Pendulum formula there occur two times t and t', t being the time of oscillation when the pendulum is hanging from the knife edge a (see figure) and t' when hanging from b. These times should be as nearly equal as possible. In the ordinary method of adjusting, the movement of either of the weights A or B probably alters *both* t and t'. By using the following method, which occurred to me while working with this pendulum in November, 1902, it is possible to adjust t' without altering t, so that the use of the pendulum becomes more methodical.

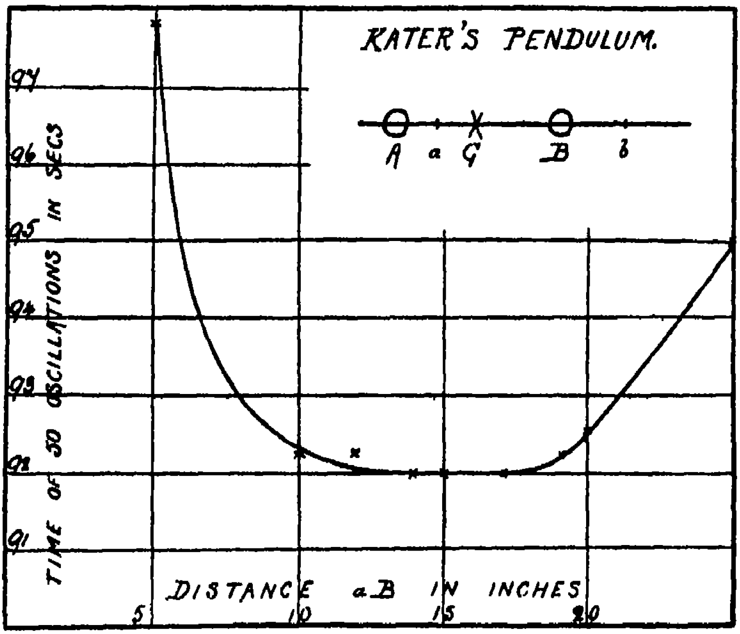
If the pendulum is hung from a, and the weight B is as far below a as A is above it, then if the rod were weightless the time of oscillation would be infinite. In the practical case it is very large. Moving B a short distance down the rod makes this time smaller. But when the distance aB is considerably greater than aA, then increasing aB will increase the time of oscillation just as in a simple pendulum. There must, therefore, be a position of B for which the time is a minimum. The figure shows an actual curve where the distances aB are abscissæ and the times of 50 oscillations ordinates.

The important point about this curve is that for six inches at least the movement of B has hardly any effect upon the time t. It is clear that this same movement will have a very decided effect upon t'. We have, therefore, a means of altering t' without altering t. In using this method as a laboratory method the sequence of operations is :—

(1) Hanging the pendulum from a, begin with B near a, and take the times for say 50 oscillations for various distances aB. Draw the curve and note the range over which B can be moved without altering $50t$ more than $\frac{1}{4}$ second.

(2) Leaving B in the middle of this range hang from b, take a reading of $50t'$, and if necessary move the knife edge b till $50t'$ is within two seconds or so of the minimum value of $50t$. It is clear that this movement of b will not have much effect upon the curve, since b is light compared with B.

(3) Now move B within the range till t' is as near the minimum t as it can be got. The final readings may now be taken.



A and B, heavy movable bobs. a and b, movable knife edges.
G, position of centre of gravity.

Formula: $$\frac{8\pi^2}{g} = \frac{t^2 + t'^2}{ab} + \frac{t^2 - t'^2}{aG - bG}.$$

PROCEEDINGS

OF THE

University of Durham Philosophical Society

(ABSTRACTED FROM THE MINUTES).

Thursday, 29th October, 1903.

JOINT MEETING OF THE CHEMICAL AND PHYSICAL AND THE BIOLOGICAL SECTION.

(HELD IN THE COLLEGE OF SCIENCE, DR. SMYTHE IN THE CHAIR.)

The following Sectional Officers were elected :—

Dr. SMYTHE, *Chairman Section* A.
Mr. ROBINSON, *Secretary Section* A.
Mr. MEEK, *Chairman Section* B.
Mr. WOOLACOTT, *Secretary Section* B.

Mr. R. R. SWANN was elected a member.

Thursday, 18th November, 1903.

GENERAL MEETING.

(HELD IN THE COLLEGE OF SCIENCE, PROFESSOR BEDSON AND AFTERWARDS MR. HODGKIN IN THE CHAIR.)

Mr. C. Bryner Jones read a paper on "The Development of the British Horse."

The Rev. Dr. H. Gee was elected a member of the Society.

The following Officers were elected :—

President

THE WARDEN.

Vice-Presidents

PROFESSOR LEBOUR.
DR. MERZ.
PROFESSOR LOUIS.
PROFESSOR STROUD.
DR. GEE.
PRINCIPAL GURNEY.

Hon. Secretaries:

MR. J. W. BULLERWELL.
MR. S. H. COLLINS.

Committee:

PRINCIPAL F. B. JEVONS.
DR. A. L. PERCIVAL.
DR. W. M. THORNTON.
MR. R. R. SWANN.
MR. A. BRENNAN.
MISS LEBOUR.

The Treasurer's report was received and adopted.

Tuesday, 1st December, 1903.

BIOLOGICAL SECTION.

(HELD IN THE COLLEGE OF SCIENCE, MR. MEEK IN THE CHAIR.)

Mr. C. M. Dodd was elected Secretary *vice* Mr. Woolacott, resigned.

Mr. Meek read a paper on "Gammarus Duebeni."

Thursday, 10th December, 1903.

CHEMICAL AND PHYSICAL SECTION.

(HELD IN THE COLLEGE OF SCIENCE, DR. SMYTHE IN THE CHAIR.)

Mr. F. C. Garrett read a paper on "The bases contained in shale oil."

Mr. J. C. Brown read a paper on "Molybdenum."

December 12th, 1903.

MATHEMATICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR SAMPSON IN THE CHAIR.)

Messrs. McKenzie, Goldsbrough, Adamson and Van der Heyden read papers dealing with the first portion of "Modern Analysis," by E. T. Whittaker.

Friday, 12th February, 1904.

CHEMICAL AND PHYSICAL SECTION.

(HELD IN THE COLLEGE OF SCIENCE, DR. SMYTHE IN THE CHAIR.)

Mr. Lomax and Mr. S. Wolff were elected members.

The Rev. Mark Fletcher read "Crystallographic notes on a mineral from Norway."

Mr. G. H. Thompson read "Practical notes on the use of Kater's pendulum."

Thursday, 18th February, 1904.

GENERAL MEETING.

(HELD IN THE COLLEGE OF SCIENCE, PROF. STROUD IN THE CHAIR.)

Mr. W. Hall was elected a member.

Professor Gilchrist read a paper on "Canada."

Thursday, 3rd March, 1904.

CHEMICAL AND PHYSICAL SECTION.

(HELD IN THE COLLEGE OF SCIENCE, DR. SMYTHE IN THE CHAIR.)

Mr. C. Bryner Jones was elected a member.

Professor Louis read a paper on "The Northernmost railway in Europe."

March 12th, 1904.

MATHEMATICAL SECTION.

(AT THE COLLEGE OF SCIENCE, PROFESSOR SAMPSON IN THE CHAIR.)

Mr. G. H. Thomson and Professor Jessop read papers dealing with the second portion of "Modern Analysis."

Thursday, 19th May, 1904.

(HELD IN THE CASTLE DURHAM, DR. JEVONS IN THE CHAIR.)

Dr. Bradshaw was elected a member.

Dr. Gee read a paper on "The Scottish invasion of Newcastle and Durham in 1640."

LIST OF MEMBERS OF THE SOCIETY.

* *Denotes an original member.*

Adams, Rev. W. R., B.A.
Alexander, F. H.
*Armour, A. L.
Ashby, A. S., B.Sc.
*Baker, T., M.Sc.
Barnard, Rt. Hon. Lord, D.C.L.
*Bedson, Professor P. P., M.A., D.Sc.
Belger, H.
Birchall, Miss D. E., B.Sc.
Black, T. P., M.A., B.Sc.
*Bolam, R. A., M.D.
Brack, Rev. M., B.A., B.Sc.
Bradshaw, Dr. F.
*Brady, Professor G. S., M.D., LL.D., D.Sc., F.R.S.
Brennan, A., B.Sc.
Brown, J. C., B.Sc.
Bryant, C. H., M.D.
*Bullerwell, J. W., M.Sc.
Burnett, Miss K., B.Sc.
*Cairns, Mrs. C. W., B.Sc., B.Litt.
Cairns, C. W., M.Sc.
*Campbell, William, M.Sc., Ph.D.
Carr, Miss A. M.
*Caunt, G. W., M.A.
Collins, S. H.
Cook, G. W.
Cousins, H. W., M.Sc.
Cullen, H. R., M.A.
*Dale, Sir David, Bart., D.C.L., D.L.
Dobbson, H.
Dodds, Roger, A.Sc.
Dow, C. R., B.Sc.
Dudley, C. R., A.Sc.
Dodd, C. N., B.Sc.
Duncan, J. B., B.Sc.
Dunn, J. T., D.Sc.
Firth, W. W., M.Sc.
Fletcher, Rev. Mark, M.A.
*Fowler, Rev. J. T., M.A., D.C.L.
Gardner, J. C., B.Sc.
*Garrett, F. C., M.Sc.
Gee, Rev. H., M.A., D.D.
Gill, E. Leonard (*Associate Member*).
Gilchrist, Professor D. A., M.Sc.
Godwin, Rev. G. H., M.A.
Goldsbrough, G. R., B.Sc.
*Gravell, John.
*Gray, W. R. H., M.A.
Greig, R. B.
Gurney, Miss L. M., B.Sc.
Hall, A. A., M.Sc., Ph.D.
Hall, W.
Hatton, R. G.
*Havelock, T. H., M.A., M.Sc.
*Heawood, P. J., M.A.
Hepple, R. B.
Heslop, Miss M. K., A.Sc.
Hodgkin, T. E.
Hodgson, B.
Holohan, M., B.Sc.
Horsley, S. G., B.Sc.
*Howden, Professor R., M.A., M.B.
Hutty, Miss J. W., A.Sc.
Jaques, A.
Jeffrey, E.
*Jessop, Professor C. M., M.A.
*Jevons, F. B., M.A., D.Litt.
Jones, C. B.
Kitchin, The Very Rev. Dean, M.A., D.D.

Langdale, A. O.
Laws, A. R., B.Sc.
*Lebour, Professor G. A., M.A., M.Sc.
Lebour, Miss M. V., B.Sc.
*Louis, Professor Henry, M.A., A.R.S.M.
Lovibond, J. L., M.A.
Lyle, R. P. Ranken, M.D.
Mack, G.
Martin, J.
Mason, F. E. W., B.Sc.
Matthews, Miss G.
Maxwell, W. W., A.Sc.
McKenzie, E., B.Sc.
*Meek, A., M.Sc.
Merrick, A., B.Sc.
Milburn, W.
*Merz, J. T., Ph.D., D.C.L.
Moles, T. W., B.Sc.
*Murray, Professor George, M.A., M.D.
Owen, Principal Sir Isambard.
O'Connor, Miss E.
Osmund, C. W.
*Patterson, R. J., M.Sc.
Pearce, Rev. R. J., M.A., D.D.
*Peacock, Miss M. L., A.Sc.
*Percival, A. L., M.D.
Pettigrew, J.
*Philipson, Professor Sir G. H., M.A., M.D., D.C.L.
Philipson, W., A.Sc.
*Potter, Professor M. C., M.A.
Potts, G., B.Sc., Ph.D.
*Redmayne, R. R., M.A.
Richardson, W. G., M.D.
Riddell, J. W.
Robinson, A. C., B.Sc.
Rollin, C., B.Sc.
*Sampson, Professor R. A., M.A., D.Sc., F.R.S.
Short, A., B.Sc.
Smith, S. P., B.Sc.
Smith, S.
Smythe, J. A., M.Sc., Ph.D.
Sodeau, W. H., B.Sc.
*Stroud, Professor Henry, M.A., D.Sc.
Stuart, C. E., B.Sc.
Tate, A. E., B.Sc.
Thomson, G. H., B.Sc.
Thornton, W. M., D.Sc.
*Todd, J. J., A.Sc.
Treble, R. L., B.Sc.
Treble, J. N., B.Sc.
*Urwick, W. E., M.A.
Van der Heyden, C. J.
*Watson, F. B., M.A., M.Sc.
Welford, R., M.A.
Widdas, H.
Willcox, F. A., B.Sc.
Woolacott, David, M.Sc.
Wright, Prof. Mark R., M.A.
Wright, Miss E. E., B.Sc.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY

Balance Sheet for Session 1903-1904.

Income	£	s	d	Expenditure	£	s	d
To Balance from Session 1902 3	17	11	0	By Printing and Issuing Notices of Meetings	5	8	5
,, 3 Subscriptions, 1901 2	0	15	0	, Printing Proceedings	19	4	6
,, 18 ,, 1902 3	4	10	0	, Printing Authors Reprints	2	10	0
,, 82 ,, 1903 4	20	10	0	Expenses of holding Meetings	2	18	1½
,, Authors' Reprints	2	10	0	,, Secretarial Expenses	2	16	0
,, Sale of Proceedings	0	2	6	, Assistant Treasurer s Commission	0	12	0
				Balance in Treasurer s hands	12	9	5½
	£45	18	6		£45	18	6

Examined and found correct,

HENRY LOUIS, *Auditor*

October 13th, 1904.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

SPARK-GAP EXPERIMENTS FOR DETECTING RADIO-ACTIVITY, AND SOME PHOTOGRAPHIC RESULTS SHOWING THE GREAT PENETRATING POWER OF CERTAIN RADIUM RAYS.

By PROFESSOR H. STROUD, M.A., D Sc.

[Read February 9th, 1905.]

During the Session 1902-1903, Mr. T. P Black made a series of experiments in the Physical Laboratory of Armstrong College on the conditions determining the production of sparks at one of two alternative spark-gaps, when these spark-gaps were subjected to sudden electric discharges from the exterior coatings of Leyden jars. In May, 1903, he found, other things being equal, a radioactive substance would determine where the spark should pass, and thus a sensitive method for detecting radioactivity was obtained. His experiments on the penetrating action of the γ rays from radium were described in *Electrician* (vol li , p. 732) Since 1903, these experiments have been continued, and the author showed the improved arrangement now adopted

The plan of the experiments is somewhat similar to that employed in the sudden discharge effects studied, by means of Lichtenberg figures, by the late Lord Armstrong and the author.

The interior coatings of two large Leyden jars are charged by a Tudsbury[1] influence machine, the exterior coat-

[1] This machine is of the Wimshurst type, but the moving parts are enclosed in a case containing carbon dioxide under pressure. The usual pressure is from 50 to 60 pounds per square inch.

ings, to facilitate charging, being joined together by a long coil, C, of many turns The exterior coatings are also connected to two similar spark-gaps, (1) and (2), between small balls about one millimetre apart, arranged in parallel. When the main spark of the machine occurs, a sudden discharge is produced from the exterior coatings of the jars, and may, owing to the impedance of the coil, C, give a spark at (1) or (2) or both.

The length of the machine spark is so adjusted that sparks do not always pass at either of the spark-gaps (1) or (2), when no radioactive substance is near either gap.

The object is to make the discharge as sudden as possible, because under these circumstances it is found that any inequalities of the surfaces of the balls at the spark-gaps produce little effect, and the gap where the spark occurs will be determined by the ionisation of the air between the balls of the gap.

Experiments were shown in which a lead slab one inch thick was placed near each spark-gap and five milligrams of radium bromide in the usual mica-covered box, enclosed in a glass airtight cell, were arranged successively on the sides of the lead slabs away from the spark-gaps, (1) and (2). The radiation had thus to pass through an inch of lead in order to affect the gap. It was shown that the spark was determined by the presence of the radium box next the lead, taking place at (1) when the box was next the lead in the neighbourhood of (1) and at (2) when the box was next the lead in the neighbourhood of (2).

A piece of pitchblende near either gap was also shown to determine that the spark occurs at that gap. The same was shown in the case of a piece of uranite.

In the spring of 1904, the author mentioned in letters to *Nature* and *Electrician* that he had obtained photographic reproductions of the parts in relief on coins by means of radium rays.

In one case ten milligrams of radium bromide, contained in the mica-covered box, were placed on a pile of thirteen pennies supported three or four millimetres above a

photographic plate on which a sixpence was directly laid, the sixpence being immediately under the pile of pennies. After three days' exposure in the dark, a picture of the parts in relief on the sixpence was obtained, the raised parts being dark in the positive.

Next a half-crown and some sixpences were exposed on a photographic plate about four cms from ten milligrams of radium bromide for ten days and it was found that all the details of the under sides of the coins were clearly reproduced.

These experiments indicate how, with coins directly in contact with the photographic plate, the outline of the raised parts is distinctly shown, the clearness of the details being obtainable by the nearness of the coins to the plate.

Several experiments illustrating radium phenomena were shown, one, illustrating the power of radium rays to discharge electrified bodies, was of a simple and interesting character. A Leyden jar was charged, and the knob arranged just beneath the point of support of a pith ball suspended at the end of a silk thread, the knob and ball being at about the same level The ball was charged and repelled. On bringing the radium box near the pith ball it was discharged, and fell back to the jar for another charge. The effect of the radium on the Leyden jar charge was so slight during the short time required to discharge the pith ball that the action could be repeated a large number of times.

If the radium was left a few inches from the knob of a moderately charged Leyden jar, the pith ball was discharged and remained in contact with the knob of the Leyden jar. In this case, if the radium was covered with a thick (half an inch) layer of lead, the pith ball was repelled, and fell back in contact with the knob on removing the lead. The hand was also shown to act similarly in place of the lead. If a very thin sheet of lead was used then the ball was repelled and fell back again slowly, and so on for many times without further action on the part of the experimenter.

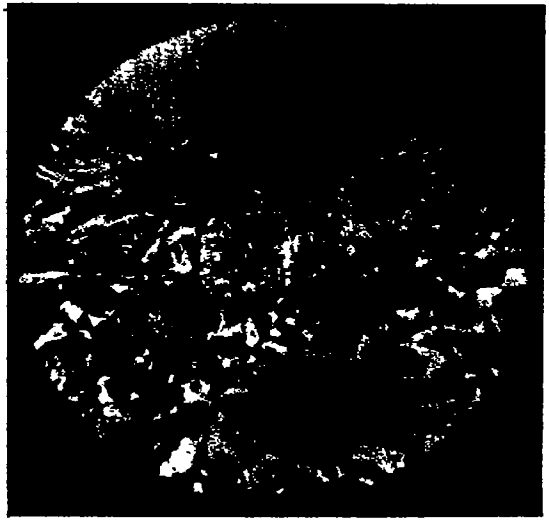


FIG. 1.

The lower half of the figure is the Granophyre, A, the upper half the Dolerite. B. C is a portion of the phenocryst, faulted in the middle and showing the zone of corrosion, D. E is the band of contact minerals which is broken through by the offshoot, F

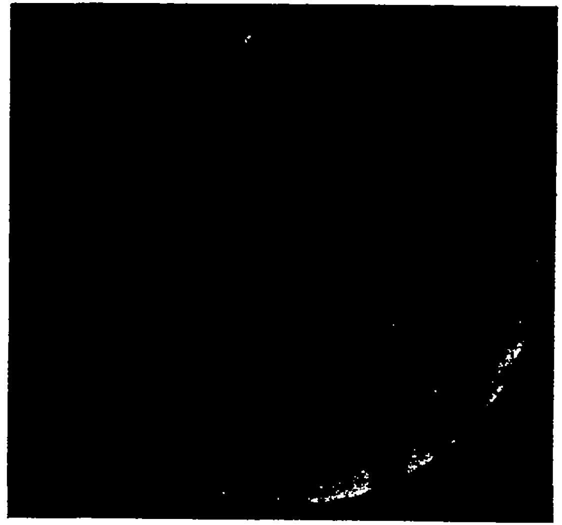


FIG 2.

B represents the Dolerite, C the rounded phenocryst with corroded border, D, broken through and faulted by three offshoots, F, from the Granophyre. The two offshoots to the left unite after passing through the large crystal and form the patch of acidic matter, G, in the midst of the Dolerite.

Notes on a Contact Rock from the Island of Mull.

By John Armstrong Smythe, M.Sc., Ph.D,

[Read February 23rd, 1905.]

The specimen to be described was found at the junction of the basic and acidic rocks which make up the mass of Beinn a Chraig, a hill rising steeply to a height of 1,939 feet from the shores of Loch na Keal in the Island of Mull The north side of the hill is of basic rock and the junction of this with the acidic rock on the north-west of the hill, whence the specimen was got, is about 1,000 feet high.

A thin slice made of this contact rock shows the following characters:—The acidic rock is a Granophyre somewhat decomposed, consisting largely of felspar and quartz, with a little altered mica. Micropegmatite is well developed. The basic rock is a Dolerite, with felspar largely predominating, and augite in granular patches. Embedded in it is a large phenocryst of a felspar allied to Labradorite and well twinned. A zone of corrosion surrounds this crystal and its angles are rounded off.

The junction of the Dolerite with the Granophyre is a thin band of green contact minerals,[1] with a fairly straight edge on the basic side, but somewhat jagged on the side of the Granophyre, the irregularities fitting round crystals of quartz and felspar. In other words this band is allotriomorphic with respect to the components of the acidic rock.

Piercing this band of contact minerals are three offshoots from the Granophyre, two of which come to a head in the phenocryst, while the third, bursting through this, passes into the Dolerite beyond. The general trend of these apophyses is along the twinning planes of the crystal. In their course they have faulted the phenocryst in several

[1] These contact minerals are heterogeneous, and not glassy. Unfortunately the slide was lost before they were further examined.

places. A fourth offshoot, clearing the phenocryst, has its foot sealed off by the band of contact minerals. The material of the offshoots is micropegmatite mixed with small quantities of green contact minerals. In one case, two of these tongues from the acidic rock unite after passing through the phenocryst, and form a nest of micropegmatite in the midst of the basic rock.

From the observations just detailed the physical history of the rock may be inferred. The first stage of which we have evidence is the formation of felspar phenocrysts in a basic magma. These were afterwards corroded by the magma, the second generation of felspars was formed, and the whole consolidated. The resulting Dolerite was then invaded by an acidic magma, some of which was squeezed into cracks in the basic rocks, and there solidified, forming the apophyses. Metamorphism now set in at the junction of the two rocks, resulting in the production of the green contact minerals. This was followed by the solidification of the acidic magma into Granophyre, and then by the consolidation of the band of metamorphic minerals.

Thus the intrusive nature, and, therefore, the later age, of the acidic rock, can hardly admit of any doubt; and the evidence of this section confirms the view now generally admitted, though once strongly opposed, that the acidic rocks of the Western Islands of Scotland are of more recent date than the basic rocks.

The productions of two microphotographs of this rock-slide are here reproduced. The magnification is about 12 diameters.

Notes on Abnormal Flowers of *Lilium Martagon* (Linn.).

By Arthur Brennan, B.Sc

[Read February 23rd, 1905.]

Material was collected in the summer of 1904 from a plant of Turk's Head Lily (*Lilium Martagon*, Linn.) for the sake of the large stamens and ovaries which are convenient for laboratory work. The flowers were gathered when just about to open and the stamens and ovaries preserved.

About twenty flowers were collected from one plant, but only one exhibited any deviation from the normal type. The abnormality was only observed on the removal of the perianth leaves and was seen to be confined to one stamen and the lower portion of the pistil. The remaining five stamens were quite normal externally, and on subsequent examination under the microscope were found to be almost fully developed. The gynœcium, however, consisted apparently of two nearly mature carpels, the third carpel being reduced to a long, narrow strip and containing no ovules. This carpel was displaced and its normal position occupied by the stamen which had become joined to the ovary. The style was but poorly developed and the stigmatic surface at the top was very much reduced. Although two of the carpels contained ovules, it would appear to be improbable that any seed would have been produced.

A microscopical examination of a section taken through the junction of the stamen and the ovary showed that fusion of the tissues had occurred in the upper portion of the ovary only. A common epidermis joined both stamen and carpels. One half of the stamen was quite normal in appearance, possessing fibrous and tapetal layers with mature pollen grains in the loculi. At the point of junction soft parenchymatous cells replaced the fibrous and tapetal layers.

The vascular bundle usually present in the centre of the stamen was fully developed. Of the carpels one seemed to be of ordinary appearance and contained the usual two rows of ovules. The second and third carpels were joined to the stamen and one half of each had a characteristic normal appearance, vascular bundles, parenchyma, and ovules being nearly fully developed. Each contained but one row of ovules.

The following summer (1905), the same plant was again examined and there were found to be three abnormal flowers: in two cases stamens had again fused with the ovary, and in the remaining flower, C, the perianth and the stamens had become united.

The deviations from the normal type may be seen in the following table:—

Lilium Martagon (LINN.).

	Floral Formula.	
Normal	. P_{3+3} A_{3+3} $G_{(3)}$	
A 1904	P_{3+3} A_{3+2} (A_1G_2)	One carpel rather reduced.
B 1905	P_{3+3} A_{3+2} (A_1G_2)	Style and stigma absent.
C 1905	P_{3+1} A_{3+0} (P_1A_2) $G_{(3)}$	The pistil was bent; one part perianth and two stamens absent.
D 1905	. P_{3+1} A_{3+0} (A_2G_2)	Two parts perianth, two stamens and one carpel absent

The absence of the style in the case of flower B would appear to indicate a reversion to a type approaching that of the *Tulipa* (to which *Lilium* is closely allied), where the style is normally absent.

In the case of flower C, where a fusion of a part of the perianth with two stamens has occurred, it may be held to indicate possibly the commencement of the modification of the stamens into perianth leaves, which would thus produce the so-called "double" flower.[1] Double flowers are more or less normal garden varieties in the case of the allied genus *Tulipa*.

In three cases (A, B, D) out of four abnormal flowers it will be noticed that the stamens and the gynœcium have

[1] Seemann, *Journal of Botany*, 1866, vol. ii., p. 177. (Cases are quoted of double flowers occurring in *L. Martagon* and *L. candidum*.)

become fused. Masters[2] records a case of *Lilium lancifolium* where stamens had become united with the perianth. He considers that "adhesion as a normal occurrence, is usually the result of a lack of separation rather than of union of parts primitively separate."

Seringe[3] has observed that the substitution of segments of the perianth for stamens occurs not infrequently in *Lilium Martagon*, and further notes that in *Lilium candidum* the segments of the perianth may increase greatly in number from the two whorls normally present.

A case of *Lilium tigrinum*[4] is noticed by Masters, where "stamens were developed in the form of carpels adherent by their edges so as to form an imperfect tube or sheath around the normal pistil." He figures one where "half the structure seems devoted to the formation of ovules, while the other half bears a one-celled anther." Lindley[5] has also described similar changes in the case of a species of *Amaryllis*. Celakovsky[6] describes with figures cases of the modifications of stamens in *Rosa chinensis* and *Dictamnus albus*.

Many theories are put forward to account for these curious "sports." Some writers[7] assume that irritation of some kind or other provides a stimulus to which the plant responds in the production of these peculiar and interesting forms.

It is certainly remarkable that all the flowers on the same plant are not affected apparently to the same extent and in the same manner, at all events not in this particular case of *L. Martagon*, where only four in two years were abnormal out of a total of 48 flowers.

[2] Masters, *Vegetable Teratology*, 1869, Book I., p. 36.

[3] *Ibid.*, Book II., p. 288.

[4] *Ibid.*, Book II., pp. 306-307.

[5] Lindley, *Theory of Horticulture*, second edition, p. 82.

[6] Celakovsky, "Teratologische Beiträge zur Morphologischen Deutung des Staubgefässes, *Pringsh. Jahrbuch für Wiss. Bot.*, 1878, Band xi.

[7] Strasburger, *Lehrbuch der Botanik*, second English edition, 1903, p. 154; Goebel, *Organography of Plants*, 1900, Part I.

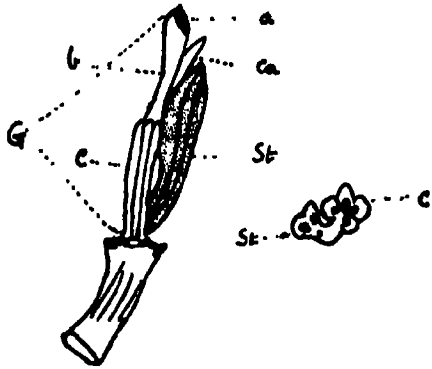


Fig. 1.

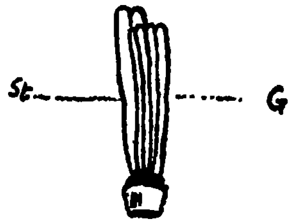


Fig 2.

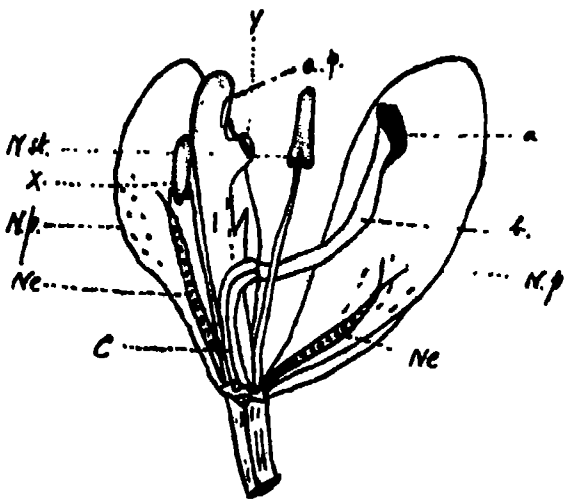


Fig. 3.

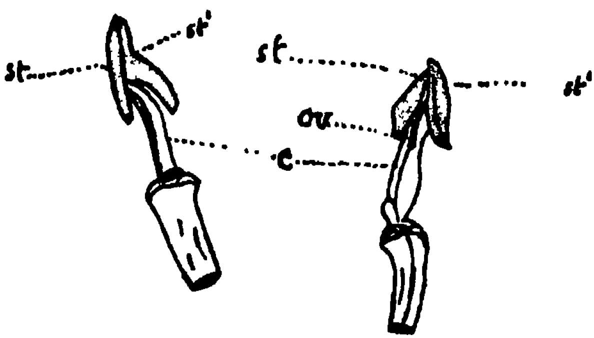


Fig. 4.

Fig. 1.—Flower A, collected 1904. The perianth and normal stamens removed; *g*, gynœcium; *a*, stigma; *b*, style; *c*, ovary; *ca*, third carpel; *st*, stamen, without a filament, consisting solely of an anther. A section through the point of junction of the ovary and the stamen is seen at the side.

Fig. 2.—Flower B, collected 1905. The perianth and normal stamens removed as before; *g*, gynœcium, without style or stigma; *st*, stamen, without filament.

Fig. 3.—Flower C, collected 1905. All normal structures removed, except two parts of perianth and one stamen; *a*, stigma; *b*, style; *c*, ovary; *nst*, normal stamen; *np*, normal part of perianth, with nectary (*ne*); *ap*, part of perianth with fused stamens *x* and *y*.

Fig. 4.—Flower D, collected 1905. The four normal parts of perianth and the two normal stamens removed; *c*, ovary, with external ovules (*ov*); *st* and *st'*, stamens. The two drawings show the front and back views respectively of the gynœcium and fused stamens.

The Pre-Glacial "Wash" of the Northumberland and Durham Coal-field.

By David Woolacott, D.Sc.

[Read March 3rd, 1905.]

The "Wash" is the most peculiar and interesting pre-Glacial valley of the northern coal-field. Its lower course from Durham to its junction with the main pre-Glacial valley of the Tyne was worked out by Nicholas Wood and E. F. Boyd in 1864,[1] and its relation to and connection with the other valleys of the two north-eastern counties have been discussed in my paper on the "Superficial Deposits and pre-Glacial valleys of the Northumberland and Durham Coal-field."[2]

In the latter work it is shown that the upper Wear and its principal tributaries flow over boulder clay and other surface deposits in well-defined valleys, which must have been developed by water-action prior to the Great Ice Age. The ancient water-course of the upper Wear extends in an easterly direction to Bishop Auckland; where, being joined by that of the pre-Glacial Gaunless, it suddenly turns to the north and follows a clearly defined course through Durham and Chester-le-Street to Norwood New Pit near Dunston, where it debouches into the valley of the Tyne. The "Wash," therefore, starts at Bishop Auckland and terminates at Dunston, its total length being about twenty miles. It is manifestly the continuation of the valley of the pre-Glacial Wear and was the path along which the waters of that river flowed before the Ice Age. Several tributary streams entered it, the chief from the west side being the Stockley, Deerness and Browney; while from the east a confluent merged into it by Bowburn and Shincliffe,

[1] "On a 'Wash' or 'Drift' through a portion of the Coal-field of Durham," *Trans. N. of Eng. Inst. Min. Eng.*, vol. xiii., 1863-1864, p. 69.
[2] *Quart. Jour. Geol. Soc. of London*, vol. lxi., No. 241, Feb., 1905.

and also one by Sherburn Doubtless many others also joined it, but more detailed and local work, than has at present been done, would be necessary to determine these. The trend of the principal valley and its chief tributaries can be distinctly followed by field-work, because they are almost continuously flanked on either side along the whole of their course by exposures of rock, which rise from under the widely-spread mantle of drift; but its exact path, and the slope of the rock-surface over which the pre-Glacial waters flowed, could only be accurately traced by the numerous borings which have been made along it. These pass through the superficial deposits down to the bed-rock, and after careful examination of the data it is possible to strip the surface deposits from the country and obtain the present direction and inclination of the ancient thalweg; and, if there have been no great differential movements since the formation of the valley, the actual slope of the old river-bed. The accompanying map of the Wear, "Wash" and Tyne shows the direction of the "Wash" and its tributaries, and the relation of it to the principal pre-Glacial valleys and their confluents. The altitude of the rock above and the depth beneath sea-level are shown by numbers prefixed with a + and − sign respectively; and the parts of the country where the rock comes to the surface are shaded, the whole of the rest being covered by surface deposits formed before, during or after the Ice Age A full description of these formations will be found in my paper already referred to.[3]

My special purpose in this paper is to deal with the slope of the thalweg of the "Wash." It is particularly interesting that the borings prove the present inclination of the bed-rock along this valley to be uniformly northwards, except at one point where the evidence is not conclusive.

The borings—which can be clearly followed on the map—along the "Wash" from Bishop Auckland to Norwood New Pit are:—

[3] *Quart. Jour. Geol. Soc.*, vol. lxi., No. 241, Feb. 1905, pp. 65-72.

Locality	Altitude. Feet.	Depth of superficial deposits. Feet.	Height of rock surface above or depth beneath sea-level Feet.
1. Bishop Auckland	300	81	+219
2. Page-Bank Colliery	258	108	+150
3. Butterby Mill	270	155	+115
4. Elvet Colliery . .	-	120	0*
5. Newton Hall, Framwellgate	230	233	− 3
6. Ford Cottage, west of Cocken Hall .	40	90	− 50
7. Chester-le-Street	41	134	− 93
8. Brown's Buildings .	110	(†)	− 55† or more
9. Near Kibblesworth ..	50	161	−111
10. Lamesley	50	166	−116
11. Near High Team .	25	158	−133
12. Norwood New Pit .	16	156	−140

* The rock-surface lies slightly below sea-level at this point, as proved by workings in Elvet Colliery

† This boring was discontinued in the superficial deposits after passing through 165 feet of them.

The present slope of the rock underlying the surface formations is from 219 feet above sea-level to 140 feet beneath in a distance of about twenty miles, or a fall of 20 feet per mile. The surface of the country at the present time along the same route is inclined at about 8 feet per mile We should naturally expect this great declivity of the ancient land surface, as the north-east of England, prior to the Glacial period, when the "Wash" was being denuded, stood several hundred—probably as much as 600 feet higher than at present,[4] and the "Wash," lower Tyne and Wear were the higher regions of the valley track of a river system, to which Dr. Smythe has suggested the name Strath-Tyne might be given. The streams flowing down these valleys, especially those that were tributaries of the main Tyne, as we have proved that running along the "Wash" was, would be of a torrential nature, and must have eroded their beds at a rapid rate; while their width proves that the valleys had been subjected to sub-aerial denudation for a prolonged period before the beginning of the Ice Age.

[4] *Quart. Jour. Geol. Soc.*, vol. lxi., No. 241, Feb. 1905, p. 75.

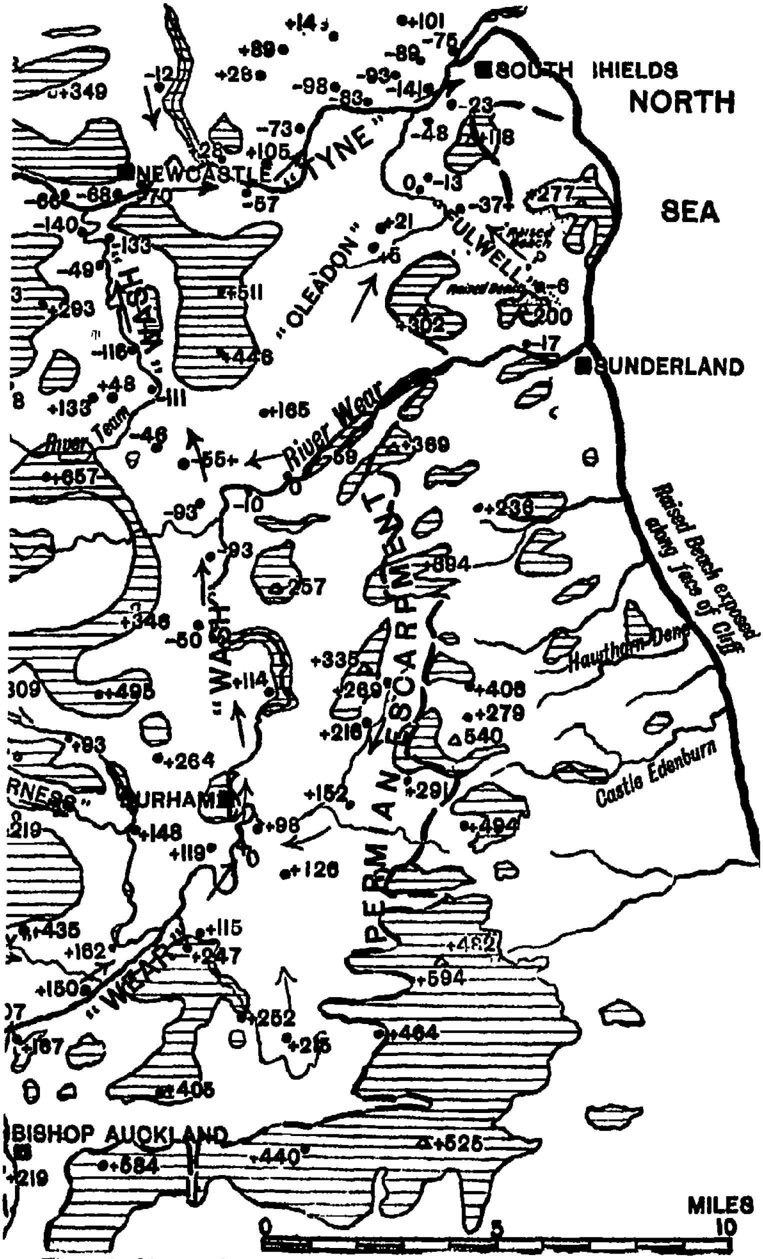


Fig. 1.*—Map of Wear, "Wash" and Tyne Pre-Glacial Valleys.

* I desire to express my best thanks to the Council of the Geological Society of London for granting permission to insert this map in the present paper.

The present slope of the bed-rock is shown in the accompanying diagram, which gives the positive and negative altitude of the rock reckoned from sea-level along the line of the "Wash." It is clear from this that the inclination of the bed-rock is a fairly uniform one in a northerly direction, the only part at which the evidence is not so full as might be desired is at Brown's Buildings, midway between Chester-le-Street and Kibblesworth, where the boring was discontinued in the superficial deposits. It is otherwise very remarkable that the declivity should be of such a regular nature, as the chance that any boring shall lie along the actual route of the thalweg or deepest part of the ancient valley is slight; and also it is very probable that differential movements of the land may have taken place in the north-east of England since the pre-Glacial period, as I have endeavoured to prove while dealing with the valley of the Tyne, and altitude of the raised beaches of the east of Durham, in the paper to which reference has already been made.[5]

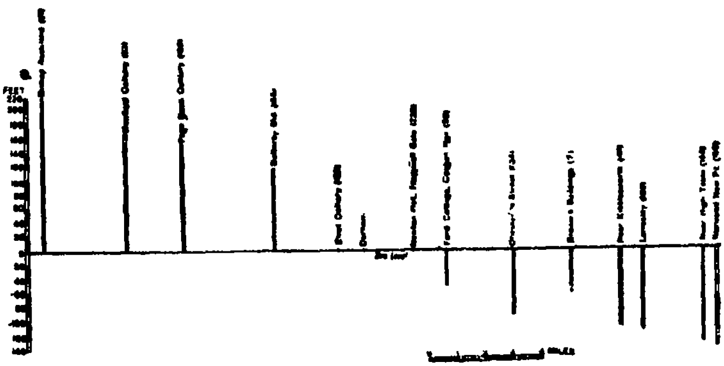


Fig. 2.

When the Ice Age passed away the rivers of Northumberland and Durham received new life, and in their upper reaches mainly flowed in the valleys they had done prior to the period of glaciation. Although the ancient water-

[5] *Quart. Jour. Geol. Soc. of London*, vol. lxi., No. 241, Feb. 1905, pp. 69 and 76.

courses were probably filled with drift to a much greater depth than at present, as the altitude at which the river terraces of the Tyne are found clearly proves, yet they were never entirely so, and hence the higher parts of the old and new river systems agree; but in the less elevated country where a great thickness of boulder clay, reaching at present as much as 233 feet, filled up the pre-Glacial water-ways, the rivers left the trend of their old courses, there cutting through boulder clay, here through rock, and at other places breaking entirely away from the line of the existing valley. The Wear flows chiefly over boulder clay from Bishop Auckland to Durham, then it pierces through rock at several places between Durham and Chester-le-Street, near which town it leaves the "Wash" and flows along an entirely new post-Glacial course to the sea at Sunderland, breaching the Permian escarpment on its way. Part of the "Wash" between Chester-le-Street and Kibblesworth becomes the water-shed between the Wear and Team, the latter river occupying the northern part of the "Wash" (see map, p. 208). The following sections across the "Wash," from the paper by Nicholas Wood and E. F. Boyd, show the relation of these rivers to the "Wash"

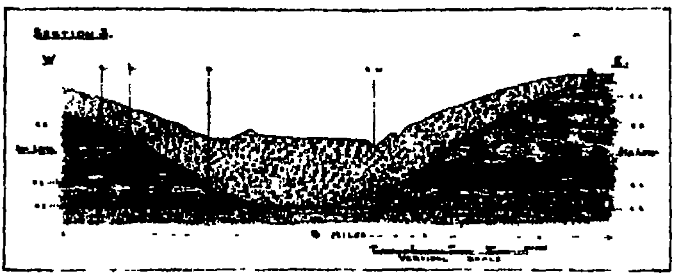


Fig. 2.

Since the Glacial period it is manifest that a considerable thickness of the drift of the northern coal-field must have been removed and the whole surface of it entirely altered. On this area there are but few parts where anything approaching the original configuration of the super-

ficial deposits remains, as the whole contour has been much changed by subsequent erosion. The deposits of sand and gravel, which are found along the "Wash" above and near to Durham City are not "terminal" moraines, as stated by some geologists, but their present mound-like contour has been produced by the denudation of the Glacial deposits subsequent to their formation.

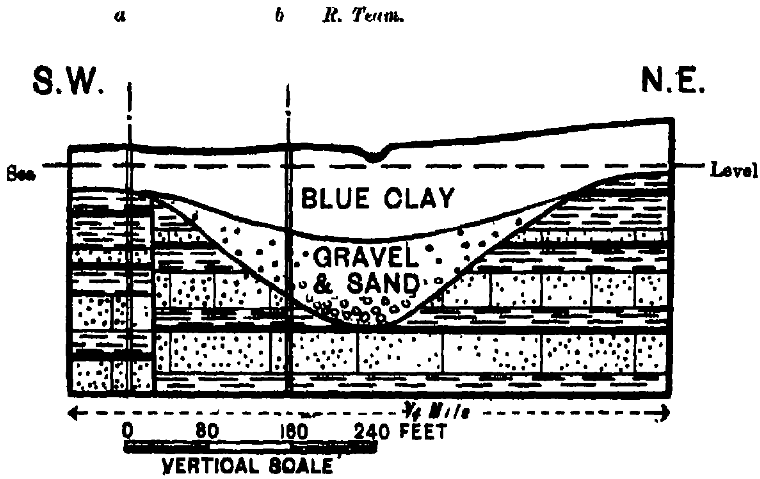


Fig 4.

DESCRIPTION OF FIGURES.

Fig. 1.—Map of the Wear, "Wash" and Tyne pre-Glacial valleys, on a scale of four inches to the mile. The dots indicate the position of the principal borings, and the numbers give the positive and negative altitude of the rock-surface. Δ = height of rock-surface on the higher ground, as obtained from the Ordnance-Survey maps. The parts of the country where the rock comes to the surface are shaded, the blank portions are covered by superficial deposits. The direction of the chief pre-Glacial valleys are indicated by arrows, and the present courses of the rivers are also shown. The thick broken line represents the trend of the escarpment of the Magnesian Limestone.

Fig. 2.—Diagram showing the positive and negative altitude of the bed-rock along the "Wash" from Bishop Auckland to Norwood New Pit. The data are obtained from the table on page 207.

Fig. 3.—Cross section of the "Wash" from Red Rose Hall Pit to Lumley Colliery. The pre-Glacial valley is denuded in the Coal Measures. It has been filled in with Glacial deposits, on top of which the River Wear flows.

a = Red Rose Hall Pit.
b and *c* = Boreholes.
d = Lumley Colliery.

Fig. 4.—Section across northern end of "Wash" near its junction with the pre-Glacial Tyne. The valley is denuded in the Coal Measures through the Bensham and Five-quarter seams down to the Hutton seam.

a = Farnacres Colliery.
b = Norwood Colliery.

The Effect of Light on Selenium.

By Godfrey Thomson, B.Sc.

[Read April 27th, 1905.]

I.—Historical.

The discovery that selenium changes its resistance in light was announced by Mr. Willoughby Smith[1] in 1873. In the years immediately following many experimenters worked upon the subject[2] and their results may be summed up as follows;—the effect is due to the light rays and not to the heat rays. The fall of resistance on exposure to light is quicker than the rise on darkening. The resistance diminishes with increased E.M.F. The resistance is always least in the direction in which the first current has passed through. A current can be produced in the selenium by exposure to light. Only the crystalline form of the element is a sensitive conductor.

Various theories were advanced and much work done without any very definite result. About 1880 Shelford Bidwell[3] began to experiment with selenium and advanced a theory which is widely although by no means universally accepted; this is, that the conductivity is due to the presence of metallic selenides. In all the preparations of selenium before this time, metallic electrodes had been used, so that undoubtedly selenides were present. He showed that pure selenium is a comparative non-conductor. Pure selenide, although a good conductor, is not sensitive to light, about 3 per cent. selenide in selenium being best. In support of his theory were the further facts that selenium conducts like an electrolyte, giving a polarisation current,

[1] Willoughby Smith, *Silliman's Journ.*, vol. 5, p. 201. *Proc. Soc. Teleg. Engs.*

[2] W. G. Adams, *Proc. Roy. Soc.*, vol. 23, p. 535; vol. 24, p. 163; vol. 25, p. 113 (with R. E. Day). Uljanin, *Wied. Ann.*, vol. 34, p. 255.

[3] Bidwell, *Nat.*, vol. 23, p. 58; vol. 32, pp. 167, 215. *Phil. Mag.*, vol. 11, p. 302; vol. 20, p. 178; vol. 40, p. 233.

and that the resistance of preparations with metallic electrodes always sinks slowly, finally falling quite suddenly to a few ohms. This he explains as due to the formation of a bridge of selenide, and showed that the application of a high voltage burnt this short circuit out, when the preparation again had a high resistance. This view is supported by an experiment described in Part 3. The most convincing demonstration of Bidwell's theory is, however, that he succeeded in preparing a mixture of sulphur and metallic sulphides so as to be also sensitive to light. He thought that the light aided the formation of selenide and thus assisted in the chemical changes of the electrolysis. He coated a copper plate with flowers of selenium, and, on covering up a portion and exposing the remaining part to light, obtained a photographic effect due to more selenide being formed on the exposed part

His explanation is obviously incomplete, since it takes no account of the necessary presence of free selenium, and in 1903 Pfund[4] advanced an altered form of this idea. He thinks with Bidwell that the selenide conducts the current as an electrolyte. The ions, however, have to pass through the mass of selenium in which they are, so to speak, dissolved, and this selenium for some reason offers less resistance to their passage when under the influence of light. In his theory, therefore, the free selenium present is the sensitive part. He was led to this conclusion by his experiments to find the point of the spectrum giving the maximum effect. He found that this point was exactly the same whatever the metal forming the selenide present and reasoned that if the light affected the combination of metal and selenium it was probable that the length of light wave would depend upon the metal used.

The Röntgen rays have an effect on selenium preparations comparable with that of light:[5] the rays from radium have also an effect.[6]

[4] A. H. Pfund, *Phil. Mag.*, Jan., 1904, vol. 7, p. 26.
[5] Perreau, *Comptes Rendus*, 1899, vol. 129, p. 956.
[6] Eug. Bloch, *Comptes Rendus*, 1901, vol. 132, p. 914. F. Hemstedt, *Drudes Ann.*, 1901, vol. 4, p. 535.

II.—A Possible Permanent Effect of Light on Selenium while Crystallising.

If one accepts provisionally the Bidwell-Pfund theory, the question presents itself, What is the change in the selenium when it is exposed to light, whereby it allows the selenide ions to pass more readily? Here one must remember that the effect of light on selenium is not instantaneous, and that when it is again put into darkness a rise of resistance goes on for hours. One possibility which suggests itself is that some change occurs in the crystallisation. If this is the case it might be possible to get a *permanent* effect on the crystallisation by exposing to a strong light during the process of crystallisation. As a preliminary experiment seemed to show an effect, more careful experiments were entered upon. The first cells used were of Shelford Bidwell's type.[7] A piece of mica is nicked along the edges and two wires wound on it, one starting from one end on the odd notches, the other from the other end on the even notches. Selenium is melted and spread on like butter and then crystallised by being kept at about 208°. They are kept hot for three or four hours and then cooled slowly. The method was to make such a cell in the dark, measure its resistance and sensitiveness, then remelt it and recrystallise in the light of an arc lamp and repeat the operations many times. The wires, however, which expanded on melting, always settled down into new positions, so that no interpretation could be put on the results. Nevertheless they seemed to point to an effect in that the resistance when crystallised in light was high and *vice versa*.

It was not found possible to make two cells sufficiently like each other to compare directly, and the alternative method seemed to offer most hope. Cells were made with solid electrodes of metal and of carbon of various designs. The trouble with these was that the selenium always made its way down between the electrodes and the non-conductor used to separate them. Casting a piece of selenium and crystallising that and measuring the resistance as the cast-

[7] Shelford Bidwell, *Nature*, vol. 23, p. 58.

ing was pressed between pieces of tinfoil was tried. The resistance depended too much on the pressure and nature of the contacts and also the surface was too small. Finally, a cell was made of the Shelford Bidwell type, but with porcelain instead of mica, narrower than formerly and with wire which does not expand on heating.[3] To be able to crystallise this always at the same temperature a naphthalene bath, kindly lent by the chemical department, was used. The results were:—

Resistance,	43·8	megohms	after	crystallisation	in light.
,,	44·3	,,	,,	,,	in darkness.
,,	39·7	,,	,,	,,	in light.
,,	41·3	,,	,,	,,	in darkness.

It was concluded that no effect greater than 10 per cent existed. The sensitiveness of cells made in darkness or in light was much easier to test than their absolute resistance and was also found to be unaffected by the light at the time of crystallisation.

III.—A Point Tending to Confirm Bidwell's Theory.

One of the cells made in working at the last question was that shown in Fig. 1, *aa*. . and *bb*.. are slips of copper separated by mica and held in a clamp. The surface is smooth and selenium spread on it. It was found, however, that after one or two meltings the resistance of such a cell sank to almost nothing. This was not due to metallic contact, and it was thought that the cause might be the same as that suggested by Bidwell to explain the low resistance of old cells, namely, the formation of much selenide, bridging across in places between the electrodes. This might be anticipated here because of the very great surface of copper. If this is correct, then the low resistance ought to be located in one or two parts of the cell, and this was found to be the case on trying the resistance between a_1b_1, b_1a_2, and so on; and it was found possible to chip away with a stout needle those parts of the selenium which contained the short circuit.

[3] "Invar" wire, a steel-nickel patent, of which a sample was kindly given me by the maker, Mr. Agar Baugh.

IV.—The Law Connecting the Intensity of Light with its Effect on a Selenium Preparation.

The relation between the intensity of light and its effect on a selenium cell is not one of simple proportion. Hence the effect of a source of light at various distances does not obey the law of inverse squares. Adams[9] concluded that the effect varied inversely as the distance, that is, as the *square* root of the illuminating intensity. Hopins[10] asserts that the effect varies as the *cube* root of the intensity. Some experiments which I carried out went to show that no very definite law existed, but that one could, under various conditions, realise both laws. If one works with strong lights and short exposures one will get Hopins' law, with weak lights Adams' law. Cells also differ in the rapidity with which they reach their minimum.[11]

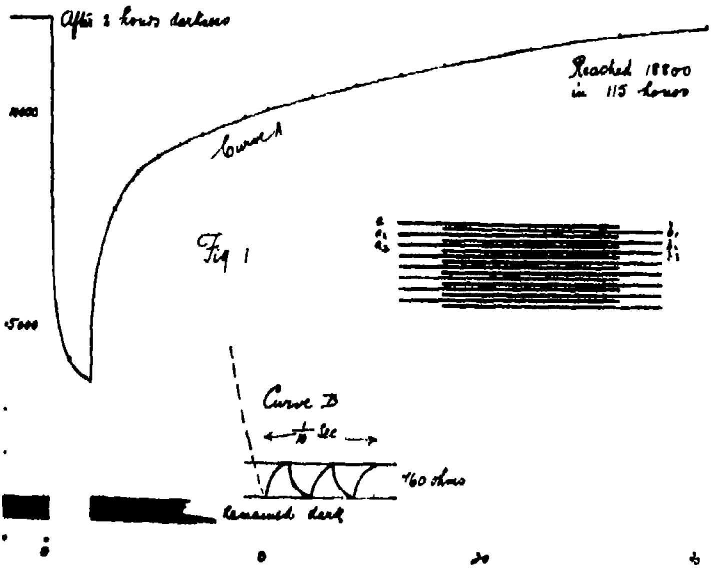


Fig. 1

V.—On the "Inertia" of Selenium Cells.

By "inertia" is meant here that property of a selenium cell due to which it only reaches its minimum resistance

[9] Adams, *Proc. Roy. Soc.*, 1876, vol. 24, p. 163.

[10] Hopins, *Journ. Russ. Phys. Chem. Ges.*, 1903, vol. 35, p. 581; *Sc. Abs.*, 1904, p. 261; *Beiblätter*, 1904, p. 723; *Fortschritte d. Phys.*, vol. 59 (2), p. 96.

[11] Mentioned by many writers. See *Ruhmer*.

some time after exposure and its maximum some time after darkening. It is mentioned by Sale [12] and has been much noticed, especially by workers trying to use selenium for light telephony and other practical purposes. As has been pointed out by Ruhmer and others, in choosing a cell for any practical purpose its inertia is as important as its absolute resistance or sensibility. At the instance of Professor Braun, of Strassburg, I carried out, in a cell of Ruhmer's construction, some tests not only for single exposures but also when exposed to rapid alterations of light and darkness. The result of two minutes' exposure is shown in curve A in Fig. 1. The ordinates are resistances and the abscissae times. Almost identical curves were obtained with home-made cells and also with Rontgen rays instead of light. The next figure is one of a series of photographs made by using an Einthoren vibration galvanometer as an oscillograph of great delicacy but long period ($\frac{1}{300}$ second) The spot of light had to be made exceedingly small and vibrated horizontally while the plate descended vertically. The selenium cell was inside a camera from which the lens had been taken. The source of light was an arc lamp, and a pendulum in the earlier and a revolving sector in the later experiments was used to make the light intermittent To make the exposures as sudden as possible both pendulum-screen and sector were made large. The times of exposure are given on the photographs. Beyond $\frac{1}{16}$ second another method had to be used, because the oscillation of the galvanometer system became so troublesome. Many plans were tried and only the following gave an approximate result.

A cylinder of hard wood was made, with on one end a ring of metal, and running from this ring and round the cylinder two spirals of metal parallel and 180° apart. A brush makes continuous contact with the ring, and another makes contact with the spirals and can be moved parallel to the cylinder axis. The sector is fastened to this cylinder and has two quadrants cut out. Hence, by moving the

[12] Sale, *Proc Roy. Soc.*, 1873, vol. 21, p. 283.

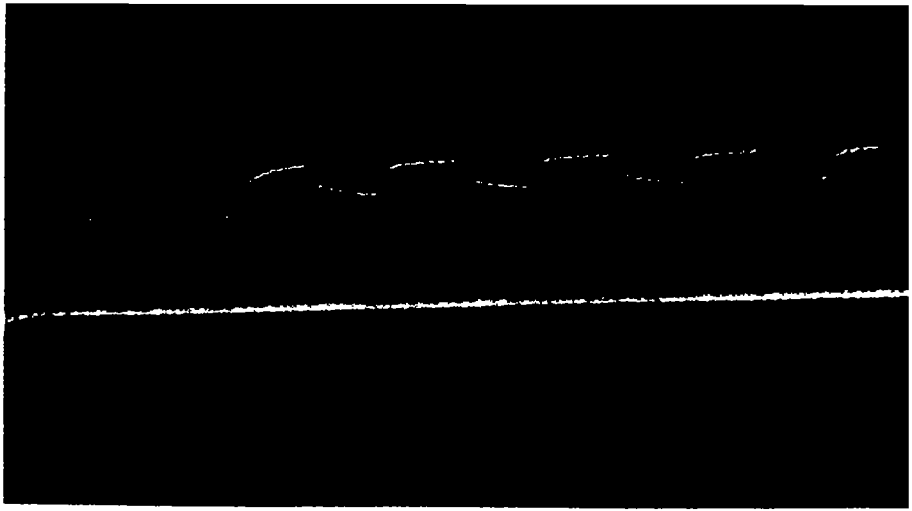


FIG. 2.
Time of exposure = time of darkness = 1 second.

second brush, one can get contact either in the middle of the light or of the dark periods or anywhere in between. The contacts had to be well oiled. Four accumulators, the selenium cell, a galvanometer and the above contact breaker were put in series Then readings were taken for various positions of the movable brush. Immediately before and after each reading were taken readings with a resistance box substituted for the selenium, in order to eliminate errors due to variations in contact. By this means curves were obtained for exposures of $\frac{1}{50}$ second but are not good enough to reproduce. They always had maximum and minimum in the proper place, however, and by measuring the difference in resistance between these the curves can be compared with those photographed, as the total drop of resistance is also known, the galvanometer being of course standardised. Curve B in Fig. 1 gives an idea of the limits between which the selenium resistance oscillates, which are much narrower than in the photographs. In arc-light telephony the arc is miles instead of feet distant and the variations in intensity are only slight, while the frequency, with sibilants, must be many thousands, so that it can be seen how small the effect must then be and how important the inertia.

The first part of this work was done under Professor Stroud at the Armstrong College, Newcastle-upon-Tyne. That relating to the "inertia" of selenium preparations (part V.) under Professor Ferdinand Braun, of Strassburg.

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Smith, Willoughby.—*Sillimans Journ.*, vol. 5, p. 301; *Soc. of Telegraph Engs.*, vol. II., p. 73 and vol. VII., p. 284; *Nature*, 1873, vol. 7, p. 303, "Effect of Light on Selenium during the Passage of an Electric Current"; *Am. Journ. of Sc. and Arts*, 1873, vol. 105 (3), p. 301.

Saunders, A. P.—*Forts. d. Phys.*, vol. 56 (1), p. 110; *Journ. Phys. Chem.*, 1900, vol. 4, p. 423, "The Allotropic Forms of Selenium."

Uljanin.—*Wied. Ann.*, vol. 34, p. 241.

White, S. A. F.—*Chem. News*, 1901, vol. 84, p. 10, "On the Effect of a High Frequency Oscillating Field upon the Electrical Resistance of Selenium and Tellurium"; *Proc. Phys. Soc. Lond.*, 1901, vol. 17, p. 800; *Forts. d. Phys.*, vol. 57 (2), p. 539.

PROCEEDINGS

OF THE

University of Durham Philosophical Society

(ABSTRACTED FROM THE MINUTES)

Thursday, 27th October, 1904.

A.—CHEMICAL AND PHYSICAL SECTION.

(MEETING HELD IN ARMSTRONG COLLEGE, DR J. A. SMYTHE IN THE CHAIR).

The following Members were elected :—Sir Isambard Owen, Dr. J. T. Dunn, Messrs. C. E. Stuart, Charles Osmund, Joseph Martin, G. H. Stanley, Misses Ellen O'Connor, Ada Carr.

The Sectional Officers for the ensuing session were elected . —

PROFESSOR STROUD, *Chairman.*
Mr. J. COGGIN BROWN, *Secretary.*

Dr. Smythe exhibited some specimens of Uranium Salts.

Thursday, 27th October, 1904.

B.—BIOLOGICAL SECTION.

(MEETING HELD IN ARMSTRONG COLLEGE, MR. MEEK IN THE CHAIR.)

The Sectional Officers for the ensuing session were elected :—

PROFESSOR GILCHRIST, *Chairman.*
Mr. A. BRENNAN, *Secretary.*

Miss Lebour exhibited some specimens of shells from Australia.

Thursday, 3rd November, 1904.

General Meeting.

(Held in Armstrong College, Professor Louis in the Chair.)

The Officers of the Society were elected :—

President

The Warden.

Vice-Presidents

Sir Isambard Owen.
Professor Howden.
Professor Louis.
Professor Lebour
Dr. Gee.
Dr. Merz.

Hon. Secretaries

Mr. J. W. Bullerwell.
Mr. S. H. Collins.

Editor

F. C. Garrett.

Committee

Principal F. B. Jevons.	Miss Lebour.
Dr. W. M. Thornton	A. O. Langdale.
Dr. J. A. Smythe.	C. Bryner Jones.

The following resolution was passed :—

"On this occasion of its First General Meeting of the Session, the Society wishes to express the sorrow and regret felt by the members at the loss it has suffered by the sad death of Principal Gurney, who always showed great interest in the *Proceedings*, to which he had contributed on several occasions."

Professor Bedson exhibited some specimens of Paraffin, and Professor Stroud exhibited a new form of Tudsbury Wimshurst machine.

Thursday, 10th November, 1904.

A.—Chemical and Physical Section.

(Meeting held in Armstrong College, Professor Stroud in the Chair.)

Mr. Wardall read a paper on and exhibited various optical instruments.

The following members were elected :—Dr. A. A. Hall, Messrs. S. G. Cook, S. W. Riddle, A. Jaques, A. Widdas, E. Jeffery, B. Hodgson.

Thursday, 24th November, 1904.

B.—Biological Section.

(Meeting held in Armstrong College, Professor Gilchrist in the Chair.)

Miss M. V. Lebour read a paper on "Notes on the Genus Clausselia."

Dr. Wm. Thornton read a paper on "The Effects of Electricity upon Living Organisms."

Thursday, 8th December, 1904.

A.—Chemical and Physical Section.

(Meeting held in Armstrong College, Professor Louis in the Chair.)

The following were elected members:—Messrs. Hermann Belger, William Millburn, Harold Burkitt, James Pettigrew and Stanley Smith.

Professor Bedson exhibited some specimens of Vanadium.

Mr. Trechmann read a paper on "Flint Implements."

Dr. A. A. Hall read a paper on "New Groups of Organic Nitrogen Compounds."

Thursday, 26th January, 1905.

General Meeting.

(Held in Armstrong College, Professor Stroud in the Chair.)

Mr. Sodeau read a paper on "Early X-Ray Work.

Mr. Clague gave a demonstration on X-Rays.

Thursday, 9th February, 1905.

A.—Chemical and Physical Section.

(Meeting held in Armstrong College, Pr
in the Chair.)

Professor Stroud read a paper on "Spark-gap Experiments."

Mr. Collins and Mr. Coggin-Brown exhibited some specimens.

Thursday, 23rd February, 1905

B.—Biological Section.

(Meeting held in Armstrong College, Professor Lebour in the Chair.)

Dr. J. A. Smythe gave a paper on "A Rock Section from Mull."

Mr. J. C. Brown read a paper on "*Janassa bituminosa* from Thickley."

Mr. A. Brennan read a paper on "An Abnormal Ovary of *Lilium Martagon*."

Thursday, 9th March, 1905.

B.—Biological Section.

(Meeting held in Armstrong College, Professor Lebour in the Chair.)

Mr. J. W. H. Brown was elected a member.

Dr. Woolacott read a paper on "The Physical Features of Northumberland and Durham," followed by a paper on "Pre-Glacial Valleys."

Thursday, 27th April, 1905.

A.—Chemical and Physical Section.

Meeting held in Armstrong College, Professor Stroud in the Chair.)

Mr. Thomson read a paper on "Selenium Cells."

LIST OF MEMBERS OF THE SOCIETY.

SESSION 1904-1905.

* *Denotes an original member.*

Adams, Rev. W. R., M.A.
Alexander, F. H.
*Armour, A. L.
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Baker, Mrs. T.
Barnard, Rt. Hon. Lord, D.C.L.
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*Garrett, F. C., D.Sc.
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Gill, E. Leonard (*Associate Member*).
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Hatton, R. G.
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Hodgson, B.
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Horsley, S. G., B.Sc.
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Jeffrey, E.
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Philipson, W., A.Sc.
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*Redmayne, R. R., M.A.
Richardson, W. G., M.D.
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*Sampson, Professor R. A., M.A., D.Sc., F.R.S.
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Thornton, W. M., D.Sc.
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*Watson, F. B., M.A., M.Sc.
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Widdas, H.
Woolacott, David, D.Sc.
Wright, Prof. Mark R., M.A.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

Balance Sheet for Session 1904-1905.

Income.	£	s.	d.	Expenditure	£	s.	d.
To Balance from Session 1903-4	12	9	5½	By Printing and Issuing Notices of Meetings	3	5	4
,, 8 Subscriptions, 1903-4	2	0	0	,, Printing Proceedings ...	7	9	6
,, 63 ,, 1904-5	15	15	0	,, Expenses of holding Meetings	4	6	3½
,, Authors' Reprints	0	12	0	,, Secretarial Expenses	2	9	5
				,, Assistant Treasurer's Commission	0	9	0
				,, Balance in Treasurer's hands	12	16	11
	£30	16	5½		£30	16	5½

Audited and found correct,

HENRY LOUIS, *Auditor*

October 23rd, 1905.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

SOME TREMATODES IN MYTILUS.

By MARIE V. LEBOUR.

[Read January 16th, 1906.]

The Trematodes form a group of parasitic flatworms having a thick chitinous cuticle without cilia in the adult, and bearing two suckers, one in the mouth region and one near the posterior end or in the centre, on the ventral surface. From these suckers the group takes its name, Trematode being from the Greek word meaning "pierced with holes." There are ectoparasitic Trematodes, which have no metamorphosis, and endoparasitic Trematodes, which have a metamorphosis in their life history. It is entirely with the latter that I shall have to do here. These form the order Malacotylea or Distomea. The life history is complicated, the fertilised egg giving rise to a larva which, to complete the cycle, enters another host, the "intermediate" host. In this host it generally gives rise asexually to a second form, and frequently these again to a third form, which enters a final host, from which the adult sexual worm is developed. The adults live in vertebrates, generally in the alimentary canal or its outgrowths, and a mollusk is always the first intermediate host and frequently the second host in which the larva encysts, but almost any other invertebrate may be the second intermediate host.

It was a great pleasure to me to discover in our local mussels, the common *Mytilus edulis*, three distinct species of these younger stages of Trematodes. The first of these is a well-known one, although apparently it has never before

been recorded for the Northumberland coast. This is the Pearl Trematode, which Dr. Lyster Jameson, in his recent researches, has proved to be the cause of the pearl in the mussel.[1] The second is the same worm that I found last year encysted in the foot of the cockle, *Cardium edule*, and published a short note on in the *Northumberland Fisheries Report* for 1904. It is apparently a new species, and a description of it has just been published by Mr. William Nicoll, M.A., B.Sc., of the Gatley Marine Laboratory, St. Andrews.[2] The third, from the mussel's liver, is possibly new. I have not as yet been able to find out the adult.

Before describing these worms, perhaps it would be as well to go over briefly the life history of a species which has been completely worked out, and for this purpose I cannot do better than take *Distoma hepatica*, the "liver fluke," although, perhaps, almost a too well-known example.

Distoma hepatica is the cause of "sheep rot" and occurs in the gall bladder and bile ducts (and their capillaries) of the sheep. The eggs pass out of the sheep, and those that get into water develop into free swimming embryos covered with cilia, having two eyes, a small enteron and a mouth. If this embryo comes across a small freshwater snail, *Limnaea truncatula*, it bores its way into its liver; here it pauses and undergoes degeneration, losing its enteron and its cilia It is now known as a sporocyst. The sporocyst is an elongated sac-like body full of balls of cells, the so-called "egg balls." These give rise to a different form called a redia, which is also elongated, but has a pharynx and an enteron. The redia breaks through the wall of the sporocyst, which closes up again. Inside the redia are formed more egg balls and some of these may develop into another form, the cercaria, which is broad and bears a tail. This escapes from the redia and finally gets out of the snail and swims about in the water by aid of its tail. It possesses all the organs of a young fluke in a rudimentary state, even the genital organs. It bears a ventral sucker and by its means

[1] *Proc. Zool. Soc.*, London, 1902, vol. i., page 140.

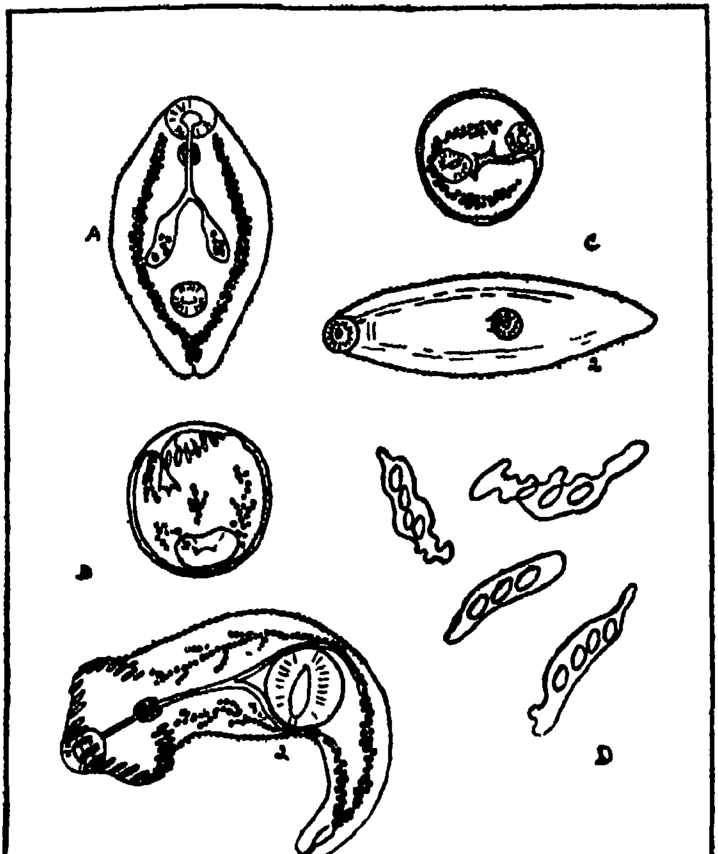
[2] *Ann. and Mag. Nat. Hist.*, Jan., 1906.

attaches itself to a blade of grass. It then secretes a mucous, which hardens round it and forms a cyst. Curled up in its cyst it waits, and should a sheep happen to eat it, the cyst is dissolved in the stomach and the worm emerges, having lost its tail during the resting stage. It makes its way into the bile duct, grows and reproduces, and so the life history begins over again.

This is practically what happens, of course, with various modifications, in the whole order. The redia generation may be omitted and the sporocysts may form a second generation of sporocysts, from which cercariæ arise The sporocysts and rediæ are always parasitic in some mollusk, but the free swimming or crawling cercaria (for all do not possess tails) may go into almost any invertebrate or may just swim about in the water before being swallowed by some vertebrate

The worms I have come across in the mussels (all from Budle Bay) are all in the cercaria stage, or rather two of them are encysted The first of these is the Trematode that causes the mussel pearls, *Leucithodendrium (Brachycælium) somateriæ*, closely allied to Distoma. It is a very well-known fact that pearls occur in the mussels of our coasts, and although many conjectures were brought forward as to a worm being the cause of these, it was only in 1902 that Dr. Jameson definitely proved the cause to be the cercaria of this Trematode *(op. cit.)*.

There are not many pearls in the Budle mussels, and these are not fine as a rule. I have, however, discovered this cercaria, which agrees in every respect with Jameson's figures, on the mantle of some of these pearl-bearing mussels. Not more than one or two on each specimen were found, and these only occasionally. Jameson found it abundantly at Piel, on the Lancashire coast; he describes it as visible to the naked eye as small yellow spots, about ½ mm. in diameter, on the mantle, the yellow colour being due to the food material in the intestine. When magnified considerably, it is seen to be of an oval form, with no tail, much the same shape as the adult worm which is found in the



EXILANATION OF PLATE

a Cercaria of Pearl Trematode from Mussel—l 0 5 mm

b (1) Encysted Cercaria from foot of Mussel—diam 0 21 mm
(2) Cercaria pressed out of Cyst—L 0 7 mm

c (1) Encysted Cercaria from liver of Mussel
(2) Cercaria pressed out of Cyst—l 0 46 mm

d Sporocysts from *Cardium edule.*

Eider Duck and Scoter (see Plate, Fig. A). It is very active and contractile and its body is covered with small sharp spines. There is a large oral sucker, and a ventral sucker which is somewhat smaller. The digestive canal is bilobed and full of yellow food material. The excretory organs are most conspicuous, consisting of granular masses each side, which unite posteriorly and open by a pore The size of the cercaria is about 0 5 to 0 7 mm. It appears to burrow into the connective tissue of the mantle, and when once settled down is, according to Jameson, surrounded by an epithelial sac formed round it by the mantle of the mussel As he says, "this epithelium appears to arise quite independently of the outer epidermis, and is no doubt due to a specific stimulation on the part of the parasite" This epithelial sac then secretes the pearl, layer upon layer. The worm may escape from the sac or may die inside the pearl Remains of dead cercariæ have been found to be the nuclei of some pearls. Professor Herdman thinks the formation of the epithelial sac can only be explained by the worm carrying in with it one or two epithelial cells from the outside, and Giard supports this view.

Jameson found the previous host of this cercaria in France to be *Tapes decussata*, in which he found sporocysts full of the cercariæ. At Piel, he found them in the cockle, *Cardium edule*, near the anterior adductor muscle, and I discovered them also in the Budle cockles, Mr. Nicoll *(op. cit.)* describes it as living in a mass of sporocysts just above the liver in the cockle at St. Andrews, and since reading his paper, I have found them abundantly in this part of the cockle at Budle. Here, then, the cockle is evidently the previous host of the Pearl Trematode. The Scoter, *Œdemia nigra*, L., is the final host, and it feeds much on mussels at Piel. The same adult worm was originally described from the Eider Duck, *Somateria mollissima, L.* Both birds are to be found near Budle; the Eider Duck is a resident, breeding on the Farnes and Holy Island, which are the only local breeding places of this species. The Scoter is a not uncommon winter visitant Either of these

birds may contain the adult worms. One peculiar feature of this cercaria, according to Jameson, is that it is never encysted; apparently the resting stage in the mussel suffices.

The second species in the Budle mussels is an encysted form living in the foot of the animal. This is the same that I found in the cockle but occurs more frequently in the mussel; every specimen, so far examined, contains them, and they were only in about ten per cent. of the cockles. This worm has just been fully described by Mr. Nicoll *(op. cit.)* [1] It cannot be seen from the outside in the mussel, whereas the tubercles found in the cockle's foot are visible from the outside. They do not appear to hurt either animal, their organs being quite healthy. There are many cysts in each foot and by gentle pressure the worm can be squeezed out (see Plate, Fig B, 1 and 2). The body is about 0·7 mm. long and is covered, except at the posterior end, with sharp spines. The head, which is broadly heart shaped, is surrounded by twenty-nine long spines. There is a large oral sucker, leading by two thick lips into a narrow intestine, which divides into two just in front of the ventral sucker, which is much larger than the oral. Down the sides run two branched excretory organs, joining posteriorly and running into a small excretory sac opening at the posterior end by a pore. Mr. Nicoll has found the adult worm in the Oyster Catcher, *Hæmatopus ostralegus*. He describes it as being very similar to the encysted worm, only longer. I might mention that I have also found this worm in cockles from Piel in Lancashire and from Loch Ryan in Galloway, also in the foot of *Mya arenaria* and *Macoma balthica*, and Mr. Nicoll has found it in the foot of *Mactra stultorum*.[2]

Before going on to the third and last species, I should like to mention another form once found in the cockles (see

[1] Since writing this, another paper, by Mr. Nicoll, has appeared, describing this worm under the name of *Echinostomum secundum*, *sp. n.*, from the Herring Gull and the Oyster Catcher.—(*Ann. and Mag. Nat. Hist.*, June, 1906, page 513).

[2] Since writing this I have discovered what I believe to be the rediæ and tailed cercariæ of this worm in the liver of the common periwinkle, *Littorina littorea* (see *Northumberland Fisheries Report* for 1905).

Plate, Fig. D). It occurred in great numbers round the liver as very contractile sporocysts with no eyes and containing three or four oval bodies in each. They were now long, now short and round, sometimes appeared to have a tail, sometimes not They were very transparent and no suckers could be made out. I mention these, as they may be found to be connected with one of the forms in the mussel.[3]

The third species occurs in the liver of the mussels at Budle. It is also encysted, the cysts occurring in between the lobes of the liver. I can see very little structure in it (see Plate, Fig. C). It occurs sparingly generally, but in one specimen it was abundant, the liver was a much darker colour and the animal did not look healthy, its reproductive organs not growing properly.

Altogether it seemed to have a deteriorating effect on the mussel. Great care must be taken in pressing the worm out of its cyst. It is elongated, its body covered with small spines, and it has an oral sucker larger than the ventral, which is slightly behind the centre In fresh specimens the granular excretory organs are clearly visible down the sides, but these granules disappear when the worm is dead. Two very faint canals can then be made out down the sides, which may be the excretory organs devoid of the granules.

I know nothing about any of the other stages of this worm, but hope to investigate the matter more thoroughly and examine several sea birds for the adult. Birds have an important connexion with Trematodes, the Pearl Trematode living in the Eider Duck and Scoter and that form from the foot of the mussel and cockle living in the Oyster Catcher. Mr. Walton, of Stocksfield, has kindly given me a list of the birds which feed on mussels. He says, "Of course there are many other birds that will eat mussels, especially during the autumn and winter seasons, as the Golden Plover, *Charadrius pluvialis*, which is very fond of the fry of mussels,

[3] This and the following species are described by me in the *Northumberland Fisheries Report* for 1905.

also the Hooded Crow, *Corvus cornix*, which is as fond of mussels as a boy is of nuts." The following is the list:—

Common Sooter ..	*Œdemia nigra.*
Velvet Sooter	*O. fusca.*
Common Shelduck .. .	*Tadorna cornuta.*
Garganey	*Querquedula circia.*
Common Pochard	*Fuligula ferina*
Tufted Duck	*F cristata.*
Golden Eye	*Clangula glaucion.*
Scaup Duck ...	*Fuligula marila.*
Eider Duck . .	*Somateria mollissima.*
Common Heron	*Ardea cinerea.*
Turnstone . .	*Strepsilas interpres.*
Oyster Catcher ...	*Hæmatopus ostralegus.*
Common Gull	*Larus canus.*
Herring Gull . .	*L. argentatus.*
Greater Black-backed Gull ...	*L. marinus.*
Kittiwake Gull	*Rissa tridactyla.*

Of these, the Shelduck, Tufted Duck, Eider Duck, Heron, Oyster Catcher, Common Gull, Herring Gull, Greater Black-backed Gull and Kittiwake are residents The Shelduck is not common, but breeds in rabbit holes on the links between Bamburgh and Holy Island The Tufted Duck is not uncommon in the winter, has bred at Wallington and has been seen on Gosforth Lake. The Eider Duck breeds on the Farnes and Holy Island and is fairly abundant, as is also the Oyster Catcher, which breeds in the same islands. The Heron is common There are heronries at Chillingham, Harbottle and Redewater, also Herons breed regularly in Dipton Woods and they are often seen by the river between Corbridge and Stocksfield. The Common Gull and the Greater Black-backed Gull are not uncommon, but do not breed in the district. The Herring Gull is common and breeds on the Farnes; also the Kittiwakes breed on the Pinnacles, but the greater number migrate. Most of them come from the Bass Rock, which is a great breeding place for them.

It seems likely that one of these common residents will be found to be the final host of this worm; at any rate, the subject is well worth investigation, as very little has been done as yet on the Northumbrian Trematodes.

ARMSTRONG COLLEGE,

NEWCASTLE-ON-TYNE,

February 1st, 1907.

DEAR SIR,

Last Session an appeal was made to members of the Society to contribute to a special "Reserve Fund," which could be drawn upon for any special expenditure which might be required for the proper illustration, etc., of these *Proceedings*. The response was fairly satisfactory, the sum of £12 14s. 6d being received, but the Publication Committee is anxious to see this sum considerably increased. If you have not already subscribed, the Hon. Treasurer (DR. J. A SMYTHE) will be glad to receive whatever you may care to contribute to this fund; I annex a list of the members who have already done so.

Yours faithfully,

F. C GARRETT,

Hon. Editor.

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Dr. T. P. Black.

The Cleveland Dyke.

By Stanley Smith.

[Read January 16th, 1906.]

This dyke appears at Robin Hood's Bay at sea-level and is traceable at varying intervals for a distance of at least 110 miles. Cutting through the Jurassic strata, which form the Yorkshire moors, and through the Trias, it passes under the River Tees in the vicinity ot Egglescliffe, and continues almost in a straight line north of Darlington through the Pennine range to Dalston Hall, south of Carlisle. On the opposite side of the Solway a number of short dykes with the same trend traverse the south-west of Scotland and strike out to sea at Prestwich on the Firth of Clyde. These are thought to be a continuation of the Cleveland Dyke, and, if this is so, the total length is 190 miles.

The highest visible outcrop is on the eastern slope of Cross Fell at an altitude of 1,700 feet. The characteristic black rock of the dyke is absent in the western escarpment, it having there failed to pierce the Carboniferous strata, and when it reappears it is lower by a thousand feet than when last seen.

The thickness of the dyke varies considerably, its maximum breadth being 100 feet; but, as seen at Robin Hood's Bay, it is only 15 feet wide. Throughout great portions of its length it never reaches the surface, having failed to do so in some places by hundreds of feet. Where quarrying has exposed its upper limit, together with the sedimentary strata above it, it is shown to terminate abruptly in some places and to taper off gradually in others. At one place only, in the whole length of the dyke, does the igneous rock overflow the surrounding strata, namely, at Bolam in the county of Durham, where a boss of no small magnitude is formed.

The basalt retains its petrological character throughout its length, and in those dykes beyond the Solway the rock

differs only in preserving, to some extent, its glassy magma and in slight alterations of composition probably due to foreign matter absorbed from the rocks traversed by them.

A large number of quarries afford ample opportunity for examining the structure of the basalt and the relation of the dyke to the surrounding strata. The quarry at the foot of Danby Moor and in close proximity to Castleton station provides a very interesting exposure. The stone having been worked out for some distance along the trend, the two perpendicular sides give quite a gorge-like appearance to the quarry, while the farther end, the site of present operations, is not unlike a rough stairway. Joints and fractures traverse the stone in all directions, breaking up the mass and giving it in places quite a fantastic structure. Some circular jointing exhibited in one of the "scabs"[1] forms a very perfect arch.

At the end by which the quarry is entered, the whinstone appears to dip beneath soft white clay or shale and at the same time to thrust thin intrusive sheets into this soft rock. On close examination, however, this clay was found to be nothing more nor less than decomposed basalt (= kaolin). The whinstone is also decomposed to a greater or lesser degree along all the joints and cracks, and frequently large patches of decomposed rock are met with; wherever the whinstone comes in contact with the surrounding strata, whether at the sides or at the top, the former is decomposed along the line of junction.

Above the whinstone are several feet of hard altered sandstone; the basalt intrudes into this.

Another very interesting quarry is at Egglescliffe. The dyke here deviates greatly from its usual straight course, and even in the quarry a slight change in direction is noticeable. A noticeable feature here is, that whereas the dyke rises perpendicularly at one extremity, it becomes slightly oblique and then practically vertical again. The length of the exposure is 250 yards and the dyke is 20 yards wide;

[1] A "scab" is a quarryman's term for the thin wall of whinstone left on either side of the worked out portion of the dyke to support it.

the quarry consists of two deep holes which are in the process of being connected by a tunnel. The deepest hole is 120 feet, being the greatest depth reached anywhere in the dyke. The basalt has here taken into itself two long strips of the white Triassic sandstone through which it cuts. The lower is 15 feet wide and the upper a little less; the length of these strips have not been determined yet, they must be, however, at least, 100 feet long Another item in this quarry worthy of interest was a long cavity found in the midst of the basalt, 30 feet in length and six feet wide in the widest part which was one extremity; from this it tapers off into a mere joint. The largest axis was coincident with the dyke. A vertical section of this was likewise pear-shaped. It was lined with calcite.[2]

The basalt (or, more correctly, the andesitic dolerite) is porphyritic in texture, tabular crystals of labradorite determining the porphyritic character. The ground-mass is crystalline or compact, according to whether the sample of rock is taken from the inner portion of the dyke or from the more quickly cooled margin. It consists of lath-shaped felspar granules and crystals of augite, magnetite or ilmenite and interstitial matter (Teall).

My analysis of a sample of basalt taken from the Castleton quarry yielded the following result:

ANALYSIS OF BASALT, CLEVELAND DYKE, CASTLETON.

Silica	56·35 per cent.
Alumina	20·24 ,,
Iron oxide	10·56 ,,
Calcium	6·25 ,,
Magnesium	2·32 ,,
Sodium	2·25 ,,
Potassium	1·25 ,,
Loss on ignition .. .	1·8 ,,

N.B.—All iron has here been calculated as Fe_2O_3. Any manganese there may be will also be included in the iron oxide.

[2] By the time this appears in print the curious cavity will have been destroyed.

This analysis differs only slightly from Mr. Stock's analysis of a sample from Great Ayton:—

SiO_2	57·57	per cent.
Al_2O_3	14·25	,,
Fe_2O_3	6·04	,,
FeO	3·95	,,
MnO	0·27	,,
CaO	6·87	,,
MgO	4·24	,,
K_2O	1·08	,,
Na_2O	2·98	,,
S	·19	,,
CO_2	·30	,,
P_2O_5	·15	,,
TiO_2	trace	,,
H_2O	1·25	,,
Total	99·14	

The analysis (by T. W. Harrison, B.Sc.) of the Kaolin from Castleton works out:—

SiO_2	52·57	per cent.
Al_2O_3	32·20	,,
Fe_2O_3	2·82	,,
CaO	1·38	,,
MgO	·99	,,
Na_2O	·15	,,
K_2O	·08	,,
Volatile at 100° C	3·40	,,
Further loss on ignition	6·19	,,
Total	99·78	

On an Exposure of the 100-Feet Raised Beach at Cleadon, 1905-1906.

By David Woolacott, D.Sc.

[Read January 16th, 1906.]

In 1877 a sea-cave was discovered in the course of quarrying operations on the eastern escarpment of the Cleadon Hills, known as the Whitburn Lizards.[1] This was not only the first exposure of the sea-worn caves of Cleadon Hills, but it was rendered specially interesting by the numerous remains found in it and an adjoining cave, including those of man, the great auk, red deer, roe, common badger, fox and water vole. These caverns lay at an elevation of about 140 feet, a height corresponding roughly with that of the ancient sea-cliff, described by the present writer as occurring on Fulwell Hills at 150 feet above sea-level.[2] This latter height probably marks the maximum depression of the coastal region of Northumberland and Durham since the Glacial period.

At the same time, a section of the 100-feet raised beach that runs almost completely round Cleadon Hills was opened out in a railway cutting on the same side of these hills. The exposure showed a considerable thickness of partially-bedded gravel resting on sea-worn rock, and overlaid by a deposit of reddish clay containing angular flints and rounded pebbles of pure quartz.[3]

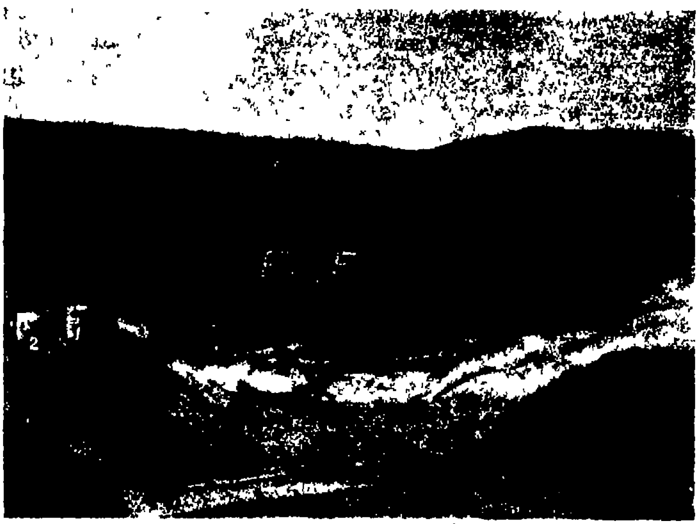
During the last few years and especially in the latter part of 1905 and beginning of 1906, this raised beach was exceptionally well exposed on the south-west side of the same

[1] *Nat. Hist. Trans. Northumberland, Durham and Newcastle-upon-Tyne*, vol. vii., 1877-1879, p. 361.

[2] *Ibid.*, vol. xiii., 1900, p. 247.

[3] *Ibid.*, vol. vii., 1877-1879, p. 364.

hills. The village of Cleadon stands on an extensive spread of marine gravel, and in two gravel and sand pits lying to the west of the village fine sections of the beach have been cut It is to the pit lying on the north side of the road running between Cleadon village and East Boldon station that my remarks specially refer. The exposure showed about nine inches of cultivated soil resting upon five or six



PHOTOGRAPH OF THE 100-FEET RAISED BEACH NEAR CLEADON VILLAGE, SHOWING SMALL FAULTS, F, F_1, F_2, FILLED WITH VERTICAL, PARALLEL TUBES OF CALCIUM CARBONATE.

The gravel deposit is worked back farther than the sand, and hence the faults do not appear to run continuously through both deposits; the connection of the two parts of one of them (F) is shown by the dotted line.

feet of irregularly-bedded gravel, consisting of the usual assortment of local and foreign rocks derived from the Boulder Clay of the district and common to the raised beaches of east Durham. The most interesting of the foreign rocks found in these deposits of shingle are the rolled flints, which have been found on the Trow Rocks, at Whitburn Lizards, Cleadon village, and in the gravel deposits resting against

the old sea-cliff on Fulwell Hills. Howse says they occur in, or are derived from, a bed which he designates as "Scandinavian drift," and which, in his classification of the superficial deposits of the two north-eastern counties, he gives as occurring between the true Boulder Clay and the upper prismatic or brick clay.[4] The most probable source of their origin appears to be from an outcrop of the Chalk that may occur on the floor of the North Sea, from which they were caught up by the great sheet of ice which passed over this area from north-eastern Europe, and came very near to, although it never actually reached, the Durham coast. Professor Kendall, in his work on the glacier lakes of Cleveland, proved, however, that it impinged on the coast of Yorkshire.[5] The flints have, in all probability, been derived from the moraine deposits left by the Scandinavian ice-sheet.

Beneath the gravel there lay some ten feet of fine current-bedded sand, the base of which has not yet been exposed, but it almost certainly rests on Boulder Clay, underlying which there will be the Magnesian Limestone. One peculiarity of this exposure was, that running more or less vertically through both the sand and gravel were several small slips or faults throwing from the fraction of an inch to several inches. These displacements have been produced by the mechanical underground erosion of the sand, parts of which have been carried away by water flowing beneath the surface on the top of the Boulder Clay. As this is an interesting example of subterranean mechanical erosion, a subject which has been somewhat neglected by geologists, it is worthy of record. Underground denudation of surface deposits of sand and gravel of a somewhat similar nature has been noticed by Professor Lebour in the Glacial deposits of the Tyne valley between Riding Mill and Corbridge.[6]

There was also another interesting feature of this deposit. The planes of slipping were filled with vertically arranged

[4] *North of England Min. Inst. Trans.*, vol. xiii., p. 170.

[5] *Quart. Journ. Geol. Soc.*, vol. lviii., p. 491.

[6] *Nat. Hist. Trans. Northumberland, Durham and Newcastle-upon-Tyne*, vol. xi., Part 2.

tubes of calcium carbonate in which there was a trace of silica. They were about a quarter of an inch in thickness and lay parallel to one another, bes being more or less cemented together along their length by a porous matrix of the same material as that which composed them; while running longitudinally through each tube was a very fine bore or series of bores. The calcium carbonate had probably been derived from the Magnesian Limestone hills lying to the east, and the rain water flowing from them through the sand lying on the impervious Boulder Clay must have, when the sand was saturated, risen up these small fault planes and deposited the tubes of calcium carbonate in them, at the same time keeping open fine capillary bores in which to rise and fall. Nothing of a similar nature has been noticed in such deposits before. The action of the rain water on the other parts of the raised beaches of east Durham has been to cement them into a hard compact conglomerate. The features discussed in this paper can still be observed, although not so clearly, but as the pit is gradually being extended opportunity may be given for further observations.

It may also be worthy of notice that in both of the Cleadon sand pits, fragmental portions of *Cyprina islandica* and *Littorina littorea* have been collected.

The Black Death in the Palatinate of Durham.

By Frederick Bradshaw, M.A., D.Sc.

[Read January 31st, 1906.]

About 1333, the Black Death appeared among the teeming millions of central China. Perhaps the earthquakes that occurred only intensified the normal overcrowding and caused an ever latent pestilence to break forth in unwonted fury. It took its fearful name from the dark purple patches that appeared on the skin and heralded a thorough disorganisation of the blood and tissues. It still lingers in the East as the Levant or Oriental plague, but improved sanitation and drainage have secured us immunity. The Black Death appeared in Cyprus in 1347 Everywhere its approach was accompanied by earthquakes, and men thought they saw it visibly marching on in the form of a dark and fetid mist. We are told of natural phenomena which turned Iceland from a well-wooded land into a barren desert and imposed a barrier of ice between Greenland and Europe.

On August 1st, 1348, the plague appeared at Weymouth, in England. It reached Durham, perhaps by sea, early in July, 1349, synchronising with a Scottish raid. It supplied the raiders with a new oath—"By the foul death of the English," and it gave as foul a death to the Scots, before they tasted of plunder, as they lay encamped in Selkirk Forest.

From what we know of Durham village-life, it is easy to understand that the Black Death found the people an easy conquest. To give even an approximate idea of the number of deaths would be impossible. We have little more than the Episcopal Rolls and Bishop Hatfield's Survey to guide us. The Prior's Rolls for these years have been lost or damaged and even our existing evidence is very scanty.

One of the first places to be attacked was Stockton. The Roll of the Bailiff of Stockton, for the year 1349, accounts for 693 boon works and we are told that the number is 257 below the proper number because of the pestilence. Possibly fear was as a helper to the plague in producing the awful mortality that occurred in Durham. The Bishop's Halmote Rolls paint the panic of the peasantry in the most vivid colours. Even before the plague actually reached them the villagers around Easington were refusing to take up vacant holdings "for fear of the pestilence." When it finally did come they apparently had not the heart to fight against it.

The Palatinate documents are curiously full about this period and the story they tell is appalling. Although we have lost the actual Court Rolls of the Prior immediately relating to the years about 1349, we have three documents in the Durham Treasury of the utmost importance. My attention was drawn to them by Mr. Kenneth Bailey, the courteous keeper of the Dean and Chapter Records, and I found that they gave the mortality among the unfree tenants in practically all the Prior's vills and, in a few cases, among the free tenants also. In the little village of Billingham, near Stockton, the deaths only just fell short of 50. In other vills it was not quite so severe but a comparison of the entry under the two Heworths, with a later entry in the Court Roll of 1373, tells us that the twenty-one tenants who died there represented two-thirds of the total number.

With regard to the Bishop's vills, our information is less precise, but the surviving Court Rolls prove that there the mortality was not less severe. Under Westhickley, we are told, "no one comes from this vill because they are all dead," and we find that only one tenant was left at Rowley. Elsewhere the tale was much the same. Poverty, and even starvation, was the the lot of those who remained alive. Bishop Hatfield's Survey and the Court Rolls illuminate each other in many vills and we can trace the effect of the plague in the fall both in the number of tenants and in the rent they paid.

It is difficult for us to realize the situation of the Bishop and the other landowners in 1350. The plague was still lurking in the land, but crops must be sown and reaped lest a more terrible famine should carry off those whom the plague had spared. But half the labourers were dead and those who remained demanded higher wages. After a succession of plentiful seasons the labourers had realized their value. Those who were personally free could and did obtain any wages they asked despite the statute of labourers. The price of food increased, and, as the Royal statutes were in force in Durham, we can assume that the employers of labour acted in Durham as elsewhere. Services had been commuted for money payments from the holders, whether bond or free, of servile lands, but now attempts were made to ask for services or an increased money payment. The free tenants on servile lands were under no obligation to pay, but rather found it profitable to give up the bond land and become labourers. It was otherwise with the serfs. Being now few in number and in minority in many villages, the *nativi*, as they were called, were victims who could not escape. The matter is not very clear, but apparently they were called upon to work for the farmers who had leased the demesne and to leave their own lands untilled. The lord refused to accept money in lieu of service, as before, and yet if the *nativus* did not till his own land he would starve, as prices were rising. The only course open to the wretched serf was to flee to another village and find work as a labourer. Fugitive *nativi* had been common enough before the Black Death, for free but landless men had often assisted a *nativus* to escape with all his family to a town, that they might have his land, holdings being scarce; but they became even more common now and their flight was often successful in the disorganised state of society. However, we are told how Thomas, the servant of John Boner, received 2s. for his trouble in capturing a serf who was escaping towards Seaham (*i.e.*, to Hartlepool, a town) in 1373.

Sometimes we find a sort of strike occurring. In 1350

a number of the *nativi* in the Ward of Chester appeared in a body before the coroner of the ward and told him that they wished to leave the land of the Bishop and to take land elsewhere. Just before Pentecost they took to Auckland the precious iron shoes of the lord's ploughs which they had used in the spring and preceding months, and from March 20th, 1350, they had neither worked for the lord nor offered to pay commutation money. The surrender of the plough-irons apparently awakened the Bishop's officials to the situation and they arrested the strikers and imprisoned them in Durham Castle till Saturday, the Vigil of Trinity. However, the steward, Sir Thos. Gray, and the receiver, Sir William de Westle, realized that harsh treatment might cause a general rising. Probably the *nativi* were equally apprehensive as to their fate, although it is not clear how the Bishop could have punished them except by depriving them of the lands, the very thing they asked for. The strikers were released on finding pledges that they would remain on the Bishop's lands and part of their debts was forgiven.

Naturally the *nativi* won in the end. They simply went on "strike" wholesale, and, as tenants were scarce, many *nativi* received larger holdings on more favourable terms than before. Harvests were good again and population increased, but the new population was different from the old in character. It was useless for the demesne lessees to demand personal service, for the surviving tenants were the judges in the Halmote Courts and without their consent nothing could be done. Free men holding bond land joined with the *nativi* against the common enemy, and in a short time, we find the greater tenants of the vill taking shares in the demesne lands and meadows and leasing their own works and the works of the cottars.

When the tenants found it impossible to avoid performing works or paying, they seem to have demanded inquisitions as to the actual amount due. The surviving bailiffs of the period before the Black Death were called upon to give evidence, as in the case of the autumn works of Sherburn,

Shadforth and Cassop, but the lord was glad to compromise by commuting the works at a sum to be agreed upon for six years. And so the process went on. The tenants challenged the right of the lord's mill to grind their corn at the old rate, and, in general, made the exaction of the old dues so unprofitable that commutation became usual.

The *nativi* silently disappeared, but there was no peasants' revolt in Durham and no formal act of manumission. For the next hundred years an agrarian revolution took place. The older *nativi* died off and the sons persistently refused to fine for their father's holding, preferring to take fresh land which had lain fallow and which they often got at a decreased rent. Instead of one tenant taking one holding, the same man took two, or one holding made up of different kinds of land, partly demesne, partly bond. He maintained that being one man he should only pay for one holding, and in the case of composite holdings each man denied that his share was bound to pay the old labour rents. The lord, at his wits' end to find tenants, was only too glad to commute tenures wholesale, or even later to let arable land to a group of sheep-masters. The *nativi* who did not appreciate a residence in their native village, were allowed to go where they chose on condition that they paid a tax of 2s. yearly, called "albanaria." But the number who paid the tax decreased at each Inquisition that was held. Their children were frequently unknown by name to the lord and so obtained their freedom by oblivion Two of the latest Inquisitions that I can trace are dated A.D. 1407. One was held at Harton, the other at Wolveston. Twenty-eight *nativi* in the northern districts and sixty-six in the south were all that the Prior had left and these represented only about twenty families, many of whom were living in Northumberland or Yorkshire. Their daughters were securing freedom for their descendants by marrying freemen and the sons of *nativi* were often forgotten or never known if born away from the Bishopric. *Nativi* may have lingered on lay estates in the wilder parts of Durham to a later date. In 1528, the Prior of Finchale held a halmote at the Bishop's

vill of Lynsak or Softley in South-west Durham, between Hamsterley and Barnard Castle, and we find that the vill contained a number of "tenants at the vill of the lord," but whether that indicated that they were personally unfree cannot be decided upon our present evidence.

The last trace of the Prior's *nativi* is in an Inquisition dated 1469, but they were few in number and were found only in South-east Durham, if not outside the Palatinate altogether. The Prior's hold over them was very uncertain and in many cases their names were unknown. In 1481, Bishop Dudley freed one of his few serfs, Thomas Copyn by name, and with him disappears the last definite traces of serfdom in Durham.

However, I must not forget one bright incident in the relations of the lord and the serf, perhaps not really unique except in our defective records. John Mouton, the Prior's serf at Billingham, one of the last of the serfs, was allowed a small yearly pension by the Prior when "prostrated with infirmity" as the Bursar's Roll of 1433-4 puts it.

When the panic of the Black Death subsided a little the Bishop's officials found that the old surveys and rentals were quite useless for ascertaining the Bishop's rights over his tenants, and so, about 1370, Bishop Hatfield undertook the compilation of the survey called by his name. It took quite 10 years to finish and, if questioned carefully, can be made to give a vivid picture of Durham before and after the Black Death, especially if read in conjunction with the Court Rolls. We see tenants denying liabilities or minimizing them. We find lands paying often largely decreased money rents, and we get vivid indications of depopulation by examination of the names of the tenants of the various holdings and the returns made as the profits of the mills, etc. At Gateshead, a water-mill and a wind-mill were leased by John of Sadberg. He used to pay £22 but the rent had to be reduced to £16 13s. 4d., presumably, through decrease of population. Again, the description of tenants' holdings frequently runs—"A.B. holds one messuage and two bovates formerly in the tenure of C.D." It is tempting to believe

that C.D. was a victim of the Black Death, but, of course, we cannot be sure.

Time prevents me from analysing the names even of the tenants of one vill, but I will only say that at Boldon two free tenants appear instead of six and that, so far from there being a demand for land, we find the same people appearing as holding different kinds of land, *e.g.*, Elias Amfray, besides a messuage and 2 bovates of land, the ordinary villein holding, has at least 3 cottage holdings and 2 lots of demesne land, and there are other vacant holdings.

The Black Death recurred during the fourteenth century, especially in 1361, and the combined result of these disasters was to hasten the emancipation of the serfs already on the way to freedom by economic causes When serfdom meant defenders turned into oppressors, it became economically unsound and was bound to end.

On Peaty Deposits from a Pit-fall at Tantobie, County Durham.

By J. A. Smythe, M.Sc., Ph.D.

[Read February 8th, 1906.]

The deposits to be described in this paper were first pointed out to me by Mr. W. A. Swallow, of Tanfield Lea colliery. The pit-fall by which they were exposed, when seen on May 15th, 1905, was a round hole about twenty-four feet across and twelve to fifteen feet deep. The section on the west side showed an old peat bed underlain by sandy clay, and covered by about a foot of soil. As the peat bed thinned out quickly to the east and the sandy clay gave place to sand, it is probable that the fall had occurred at the east edge of an old peat bog, although there were no surface indications of such. The peat contained stumps of wood and roots, some in an advanced state of decomposition, others still fresh and fibrous; and the underlying sandy clay contained a peculiar black jelly-like substance irregularly distributed in pocket and clefts. The actual quantity of this material was small, although it was fairly widely dispersed, sometimes as a thin lining to fissures in the clay. It was nowhere seen to be in actual connection with the peat, but from its occurrence only beneath it (and from chemical evidence to be given shortly), there can hardly be any doubt that it was derived from it. Some of the larger pockets, about one foot below the peat bed, yielded a few cubic inches of the deposit.

Analyses.—The deposit was seen to have a conchoidal fracture and a concentric arrangement of layers and it could be peeled somewhat like a boiled onion; on drying in air it lost 76 per cent. of water and formed a hard black substance with conchoidal fracture, grinding to a dark brown

powder. The peat, and the partially decomposed wood embedded in it, formed brown powders on drying and grinding. These three bodies will be referred to hereafter as black stuff, peat and wood.

Under the microscope, the black stuff appears as a greenish-yellow, transparent body, stratified but quite devoid of any plant structure. The air-dried samples gave on analysis:—

	Moisture.	Ash.	Volatile Matter.	Fixed Carbon.
Black Stuff	16·43	7·23	55·55	20·79
Peat	16·05	9·75	49·44	24·72
Wood	14 12	4·12	66·00	25·76

All three yield friable cokes or cokey powders, and the ash is white in the case of the peat, buff in the other two. For better comparison these results are here recalculated on the basis of dry ash-free material.

	Volatile Matter	Fixed Carbon.
Black stuff	72·80	27·20
Peat	66·66	33·34
Wood	68·48	31·52

These figures bring out clearly the similarity of the peat and wood. The somewhat higher percentage of volatile matter in the black stuff is what might be expected on the assumption that it is derived from the peat by some process of solution and deposition. The ultimate analysis[1] of the dry materials gave:—

	Carbon.	Hydrogen.	Nitrogen.	Sulphur	Ash	Oxygen (by difference).
Black Stuff ..	49·22 49·26	5·14 5·16	2·33 2·49	1·41	11 23	30·51
Peat	—	—	1·55	—	—	—
Wood ...	—	—	0·92	—	—	—

The low percentage of total carbon and the high percentage of volatile matter suggests that the black stuff is similar rather to the carbohydrates than to coal. This is brought out clearly in the following table, in which the

[1] I am indebted to Mr. E. Jeffrey, B.Sc., for the determinations of nitrogen in these samples.

black stuff is compared with three of the typical carbohydrates, namely, cellulose, starch, and cane-sugar.

	Total Carbon.	Total Hydrogen	Volatile Matter.	Fixed Carbon.
Cellulose	44·44	6·17	87·60	12·40
Starch	44·44	6·17	83·52	16·48
Cane-sugar	42·11	6·44	79·85	20·15
Black stuff (ash-free)	55·54	5·80	72·80	27·20

Extraction with Solvents.—Dry chloroform dissolves about 1 per cent. by weight of the black stuff, peat and wood after three hours' extraction. The yellow solution leaves a waxy solid on evaporation of the chloroform, and this solid, on purification by dissolving in benzene and precipitating with petroleum ether, is obtained in the form of a greenish powder, melting about 90° C. and burning with a long, smoky flame when heated on platinum. The result in all three cases is the same.

The residues from the chloroform treatment, when extracted for six hours with pyridine, yield dark brown solutions, from which acids precipitate a humus-like substance, acidic in character The amount extracted is about five per cent. in the case of the black stuff, and slightly less in that of the wood and peat.

Dr. P. P. Bedson[2] first described, in 1899, the solvent action of pyridine on coal. In extending this work, Mr. T. Baker[3] discovered that pyridine dissolves out from coal some, at least, of the constituents richer in hydrogen, and, furthermore, that the presence of these constituents influences in a remarkable way the coking power of the coal. Thus a coal with moderate coking properties is rendered non-coking by treatment with pyridine, but the pyridine extract has greatly enhanced coking properties compared with the original coal.

Exactly similar phenomena are met with in studying the

[2] "Results of the Analysis of Samples of New Zealand Coal and Amberite, and of Barbados Manjak," by Dr. P. P. Bedson, *Trans. Inst. M.E.*, 1899, vol. xvi., page 388.

[3] "The Solvent Action of Pyridine on Certain Coals," by Mr. T. Baker, *Trans. Inst. M.E.*, 1900, vol. xx., page 159.

solvent action of pyridine upon the black stuff from Tantobie. Not only do the pyridine solutions resemble those from coal, but the extracts are richer in volatile matter (and presumably in hydrogen also), and they coke much more readily than the original stuff itself, and still more so than the extracted residue. Thus, proximate analysis of the residue and extract from the pyridine treatment of the black stuff gave the following results:—

	Volatile Matter.	Fixed Carbon.	Ash
Extract ..	79·24	20·29	0·47
Residue ..	48·04	37·41	14·55

The original and the residue both gave a cokey powder; the extract yielded a compact glistening coke. Comparing these results with the original black stuff, and recalculating all on ash-free material, the results are as follow:—

	Volatile Matter.	Fixed Carbon
Black stuff	72 80	27·20
Extract	79·64	20·36
Residue	56·30	43·70

For comparison of the black stuff with coal, Mr. H Blair has kindly examined for me a bright coal with respect to solubility in pyridine, proximate composition and coking properties. The results are as follow:—

Soluble in Pyridine $\left\{\begin{matrix}33·31\\33·36\end{matrix}\right\}$ per cent.

Proximate analysis of the coal, extract and residue:—

	Moisture.	Ash	Volatile Matter.	Fixed Carbon.
Coal	0·68	3 83	33·28	62·21
Extract	—	—	60·01	39·99
Residue	—	6·65	31·07	62 28

These figures, re-calculated on the dry ash-free materials, give:—

	Volatile Matter	Fixed Carbon
Coal	34·84	65·16
Extract	60·01	39·99
Residue	33·27	66·73

The extract was found to coke much better than the original coal, and better still than the residue after exhaustion with pyridine. The relationships existing between fixed and volatile matter are quite comparable with those described above in the case of the black stuff from Tantobie

The examination of these deposits seems to point, firstly, to the derivation of the black stuff from the peat. This appears evident from the method of occurrence of the two deposits, and from their similarity in proximate composition. The absence of plant structure in the black stuff indicates that some process of solution and deposition from solution has taken place, and is in harmony with the rise in the nitrogen-content from the wood to the black stuff; since, according to Delesse[4], the woody parts of plants contain less nitrogen than the leaves, and less also than such mosses as make up part of the material of peat bogs. One would thus expect the wood to contain less nitrogen than the peat in which it is embedded, and the products of the metamorphosis of such materials, in which the woody structure has disappeared, to be richest of all in nitrogen. This is what actually happens in the case under discussion, as may be seen from the table of ultimate analysis on p 256.

Secondly, the black stuff has affinities both to the carbohydrates and to coal. The former is manifested by analyses, both proximate and ultimate, as seen from the table on p. 257, where the black stuff is compared in respect to composition with three representative members of the carbohydrate group of compounds. The latter is shown by the behaviour of the black stuff and coal towards solvents, in particular towards pyridine. Both bodies yield to this solvent acidic, humus-like substances, and their coking properties, fixed carbon and volatile matter, stand midway between those of the extracts and the residues left after extraction.

That the black stuff from Tantobie should thus resemble substances apparently standing so far apart as coal and the

[4] "Recherches de l'Azote et des Matières Organiques dans l'Écorce Terrestre," by Prof. A. Delesse, *Annales des Mines*, 1860, vol. xviii., page 219.

carbohydrates, is perhaps not to be wondered at, when the chemical relationship between coal and cellulose is borne in mind.

Some recent deposits having, apparently, some of the characters of the Tantobie black stuff have been described by Prof. H. Potonié, of Berlin.[5] They are formed on the Ahlbecker See from muddy matters containing animal and vegetable remains, and are fermented in the absence of oxygen. The consistency of these muds is that of a jelly; they are so rich in nitrogen as to be worked for the extraction of ammonia, and they show a delicate stratification and conchoidal fracture Quite recently[6] the same author has pointed out the parallelism between certain varieties of coal and peat. The peat formed under terrestrial conditions corresponds to bright coal; under water, however, an organic slime is found (for which the name "Sapropel" is proposed), which becomes gelatinous when sub-fossilised. This gelatinous form, or "Saprokoll" (corresponding to the black stuff) is, according to Potonié, the exact equivalent of dull coal or cannel, the most marked properties, common to both, being the conchoidal fracture and the large percentage of volatile matter. If cannel coal be thus regarded as derived from Saprokoll, it is clear that considerable loss of volatile matter takes place in the process, for the percentage of volatile matter in cannel seldom exceeds 50, whereas that of the Tantobie black stuff is 72·8 (both reckoned on the dry ash-free material).

[5] See *Trans. Inst. M.E.*, 1905, vol. xxviii., page 722.

[6] *British Ass. Report*, York, 1906. See also *Nature*, 22nd Nov., 1906, page 84.

The Motions of a Ship at Sea (Abstract).

By F. H. Alexander.

[Read March 6th, 1906.]

However complicated the motions of a body in space may be, they can be resolved at any instant into components about the three principal axes of the body and each component may be defined as motion in the direction of the axis, or rotation about the axis. Each may also be positive or negative in direction and have positive, zero or negative acceleration.

It is not proposed here to deal with the motions of ships due to propulsion or steering, but only with those called rolling, pitching and heaving, which so frequently cause discomfort to travellers.

Rolling is transverse, and pitching is longitudinal, rotary motion, and heaving is motion along the vertical axis. Each is of an oscillating character.

The resultant of the vertical buoyant forces upon a floating body passes through the centre of the immersed volume, and this point is called the centre of buoyancy. As the body rotates about a given axis the point moves along a curved path within the body, and the initial centre of curvature of this path in the position of stable equilibrium is called the metacentre (M). It is a well-known condition of stable equilibrium that the centre of gravity (G) of the body must be vertically below the metacentre; for under this condition inclination obviously induces a couple tending to return the body to its original position. The vertical distance between (G) and (M) is thus of importance in the consideration of stability. If, for example, a cylindrical body, of weight (W), floating parallel to its axis, and with (G) below (M), be set rolling in still water, the "righting

moment" at an angle θ is measured by the expression W $\times$ GM sin θ. As in the case of a pendulum, at small angles, and neglecting resistances, we may write this $W \times GM . \theta$ and the rolling motion then becomes simple harmonic and its period $T = 2\pi\sqrt{\frac{I}{W \times GM}}$ (where I denotes the mass moment of inertia of the body about its axis of rotation).

Now a ship is not a cylindrical body and the mathematical determination of its exact period would involve some labour, but experiments have been carried out on ships set rolling in still water, and their actual periods determined, as well as the damping effects of water friction and disturbance, bilge keels and other features. Analysis of the results shows that for most ships a sufficient approximation to the period may be obtained by the use of the above formula, provided the angles reached are not great. From the data determined by these experiments it is also possible to calculate the behaviour of the vessel among waves of given size by means of graphic integration; but there is not time or space here to explain the method. Pitching follows the same law as rolling, being in reality a form of it but about a transverse axis.

Now it is obvious, from the formula given, that a small distance between G and M will give a large period and *vice versa*, and it is within the power of the naval architect to so design his ship that, as regards rolling, this GM may be small and the motion slow and steady rather than rapid and violent. For this reason the value of GM is usually made about one foot in large passenger vessels. Pitching is less under the designer's control, for both I and GM are too great to be capable of appreciable modification.

As regards heaving, the vertical oscillations of a body with vertical sides are simple harmonic, the period being $T = 2\pi\sqrt{\frac{V}{gA}}$ (where V is the immersed volume in cubic feet, and A the volume of a layer one foot deep and of the horizontal section of the body at the water surface). Though a ship's sides are not usually quite vertical, the formula

applies with the necessary accuracy, and it is to be seen that a vessel of relatively light draught will have a tendency to a short heaving period.

Coming now to the conditions at sea, we observe that the waves passing the ship supply the forces causing the above motions, and that the main waves meet the ship successively in a regular period which may be called the period of approach, and which is dependent upon the vessel's course and speed, and upon the waves own period of passing a fixed point. The latter in free-moving ocean waves is approximately $T = \frac{4}{9}\sqrt{L}$ (where L is the length of the wave from crest to crest in feet).

It is evident that where this period of approach synchronises with the specific period of the ship's own motion, whether that motion be rolling, pitching or heaving, the successive impulses will increase such motion till, in the case of rolling, there may even be danger of overturning The navigator, by changing the vessel's course or speed, may change the period of approach and thus, to some extent, control the nature of the motions The naval architect can control them only in so far as his design may affect the specific periods of the ship herself. So that the sufferer from synchronism must still, I fear, lay most of the blame on Nature's want of consideration, until the submarine has developed into the passenger liner and can carry him safely at depths below the region of wave disturbance.

PROCEEDINGS

OF THE

University of Durham Philosophical Society

(ABSTRACTED FROM THE MINUTES).

November 3rd, 1905.

(AT ARMSTRONG COLLEGE, THE REV. DR. H. GEE AND AFTERWARDS PROF. P. P. BEDSON IN THE CHAIR.

The following new Members were elected :—Miss M. Atkinson, Mr. F. G. Trobridge, Dr. H. J. Hutchens.

The following Associate was elected :—Miss Glenny.

Dr. F. C. Garrett then read a paper on "The Norsemen in America."

The Report of the Treasurer was adopted.

The following Officers were elected :—

President :

THE WARDEN.

Vice-Presidents :

SIR ISAMBARD OWEN.	PROF. P. P. BEDSON.
PROF. R. HOWDEN.	DR. F. B. JEVONS.
PROF. M. C. POTTER.	PROF. G. S. BRADY.

Hon. Secretaries.

S. H. COLLINS.	DR. J. A. SMYTHE.

Editor :

DR. F. C. GARRETT.

Committee :

DR. F. BRADSHAW.	MISS LEBOUR.
J. W. BULLERWELL.	J. MARTIN.
A. JAQUES.	DR. W. M. THORNTON.

SECTIONAL OFFICERS.

Section A (Chemical and Physical Section).

Chairman: PROF. H. LOUIS.

Secretary: E. JEFFERY.

Section B (Biological Section).

Chairman: DR. D. WOOLACOTT.

Secretary. A. BRENNAN.

Section C (Mathematical Section).

Chairman: PROF. SAMPSON.*

Secretary: PROF. JESSOP.*

Section D (Archæological and Historical Section).

Chairman: REV. DR. H. GEE.

Secretary: C. BRYNER JONES.

November 23rd, 1905.

CHEMICAL AND PHYSICAL SECTION.

(AT ARMSTRONG COLLEGE, PROFESSOR STROUD IN THE CHAIR.)

Mr. H. Dean was elected a Member.

Dr. Black read a paper on the "Braun Tube."

Mr. A. Jaques read a note on "Alternative Views on the the Composition of Elements."

November 30th, 1905.

BIOLOGICAL SECTION.

(AT ARMSTRONG COLLEGE, DR. D. WOOLACOTT IN THE CHAIR.)

The following were elected Members :—Messrs. R. Coates, H. Crofts, H. Stephenson, J. W. D. McConnell.

Professor Brady, F.R.S, gave an address on "Disappearing and Extinct Animals."

December 6th, 1905.

MATHEMATICAL SECTION.

Professor C. M. Jessop read a paper "On the Geometrical Representation of the Imaginary Elements of Space."

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* Previously elected by Section.

January 16th, 1906.

BIOLOGICAL SECTION.

(AT ARMSTRONG COLLEGE, DR. D. WOOLACOTT IN THE CHAIR.)

The following were elected Members :—Messrs. A. Horton, P. R. Thompson, A. J. A. Woodcock.

Miss M. V. Lebour read a paper on "Some Trematodes in Mytilus."

Mr. Stanley Smith read a paper entitled "Notes on the Cleveland Dyke."

Dr. Woolacott read a short note on "Local Geology."

January 25th, 1906.

(AT ARMSTRONG COLLEGE, PROFESSOR P. P. BEDSON IN THE CHAIR.)

Professor H. Louis read a paper on "A Forgotten Corner of Russia."

January 31st, 1906.

ARCHÆOLOGICAL AND HISTORICAL SECTION.

(AT DURHAM, THE PRESIDENT IN THE CHAIR.)

Dr. F. Bradshaw read a paper on "The Black Death."

The following Members were elected :—Miss Hutchinson Professor Nichol Smith, Mr. Geo. Rushton.

February 8th, 1906.

CHEMICAL AND PHYSICAL SECTION.

(AT ARMSTRONG COLLEGE, PROFESSOR H. LOUIS IN THE CHAIR.)

Mr. H. Morris-Airey was elected a Member.

Professor P. P. Bedson gave a demonstration of the explosive combustion of mixtures of coal-dust and air.

Dr. J. A. Smythe gave a note on a deposit found in a pit-fall at Tantobie.

Mr. E. Jeffery gave a note on Kjeldahl's method of estimating nitrogen.

March 1st, 1906.

BIOLOGICAL SECTION.

(AT ARMSTRONG COLLEGE, DR. D. WOOLACOTT IN THE CHAIR.)

Professor M. C. Potter read a paper on "A Trip to South Africa."

March 6th, 1906.

CHEMICAL AND PHYSICAL SECTION.

(AT ARMSTRONG COLLEGE, PROFESSOR H. LOUIS AND AFTERWARD MR. S. H. COLLINS IN THE CHAIR.)

Mr. Alexander read a paper on "The Movements of a Ship at Sea."

Professor H. Stroud exhibited some new physical apparatus.

March 17th, 1906.

MATHEMATICAL SECTION.

Dr. T. P. Black read a paper on "Reye's Synthetic Geometry," and Dr. A. S. Percival described a simple form of Planimeter.

March 14th, 1906.

ARCHÆOLOGICAL AND HISTORICAL SECTION.

(AT ARMSTRONG COLLEGE, DR. H. GEE IN THE CHAIR.)

Dr. Gee read a paper on "Durham and Newcastle during the Rebellion of 1569."

May 23rd, 1906.

(IN THE CASTLE, DURHAM, THE PRESIDENT IN THE CHAIR.)

Mr. K. C. Bayley read a paper on "Some Notes on the Military Situation in the County of Durham during the Middle Ages."

Report of Geological Photographs' Committee, 1906.

Since the last report of this committee was presented, about forty photographs have been forwarded to Professor Watts, secretary of the British Association Geological Photographs' Committee, and the secretary has also several others ready for sending. The chief object of the committee, in connection with the Philosophical Society, is to obtain copies of photographs illustrating the geology and physical geography of Northumberland and Durham, and to forward them to the committee in connection with the British Association. The secretary—Dr. Woolacott—would be pleased to receive such photographs at any time. The following are the principal photographs that have been sent:—

Taken by Dr. Smythe.

(1) Section of the Lower Greensand, Blackgang Chine, Isle of Wight.
(2)—(6) The Whin Sill at the following places:—Bamburgh, Dunstanburgh, Cullernose, Crag Lough.
(7) Intersecting faults in Bernician beds near Cullernose Point.
(8) Nip-out of the Glebe coal, Ouseburn.
(9) Banded basalts, Ben More, Island of Mull.
(10) Ice-worn rocks, Loch-na-Keal, Island of Mull.
(11) Ben Talla (Talaidh), Island of Mull.
(12) Undercut Cliff, Laig Bay, Island of Eigg.
(13) Weathered out Dyke, Laig Bay, Island of Eigg.
(14) Blaven, Island of Skye.
(15) The Coolin Hills, Island of Skye.
(16) The Red Hills, Island of Skye.
(17) Caves in Magnesian Limestone, Whitburn.
(18) Lot's Wife, a weathered-out breccia gash, Marsden.
(19) Bedded breccia, Black Hall Rocks.
(20) The Cheviots, from Yarnspath Law.
(21) Cushat Law, The Cheviots.

Taken by Dr. Woolacott.

(23) The landslip at Claxheugh, September, 1905.

(24) Breccia gash, Marsden.

(25) Cavern in Magnesian Limestone, Wingate.

(26) Hawthorn Dene, East Durham.

(27) Boulder Clay, Hendon.

Taken by Mr. G. T. McKay.

(28) Moraine at foot of High Cup, Gill.

(29) Roman Fell.

(30) Whin Sill and Melmerby Scar Limestone, Hilton Beck.

(31) St. Bees' Sandstone, Murton village, with Murton Pike in distance.

Report of Boulders' Committee, 1905-1906.

At a meeting of the Biological Section of the Society a committee was appointed to investigate the glacial deposits of Northumberland and Durham. The work of this committee principally consists in the determination of the nature and position of the boulders that occur in the superficial formations of these two counties, and also in the observation of the direction of the glacial striæ that are exposed on the rock surface lying beneath the boulder clay. A start has been made with this work, but the committee hope that it will be carried on more energetically and by more observers in the future. The members of the committee would be pleased to give advice to any one interested in the subject.

The following observations have been made:—

(a) Glacial Striæ.

No	Place	Date	Lat. and Long.	Direction of Striæ, corrected for magnetic declination
1	Kenton Quarry	Aug. 1905	55° 1′ 10″ 1° 39′ 30″	S.E.
2	Kenton Quarry	Nov. 1905	55° 1′ 10″ 1° 39′ 30″	S.S.E. to S.E.
3	Brunton Quarry	Sept. 1906	53° 2′ 12″ 1° 37′ 43″	*Main*, 7° S. of E.
				Subsidiary, 10° N. of E.
4	Burradon Quarry	Oct. 1906	55° 3′ 5″ 1° 34′ 10″	28° S. of E.
5	Burradon Old Quarry	Oct. 1906	55° 2′ 55″ 1° 33′ 55″	44° S. of E., 20° S. of E., 56° N. of E. (in order from oldest to most recent)
6	Fulwell Quarry	Sept. 1905	54° 35′ 45″ 1° 24′ 10″	E. S.E.
7	The Flats, N. Shields	Dec. 1905	55° 0′ 50″ 1° 25′ 30″	S. S.E.

Nos. 1-5. These striæ were upon Coal Measure Sandstone.—J.A.S.

No. 6. Upon Magnesian Limestone. No. 7. Coal Measures Sandstone.—D.W.

(b) Boulders.

Boulders of the Borrowdale volcanic series from the Lake district have been observed at High Sharpley, East of Hetton-le-Hole, Consett, Wingate Old Quarry; of Cheviot porphyrite at Whitley, The Flats, N. Shields, Hendon Banks, Sunderland.—D.W.

David Woolacott, *Convener*.

LIST OF MEMBERS OF THE SOCIETY.

SESSION 1905-1906.

* *Denotes an original member.*

Adams, Rev. W. R., M.A.
Alexander, F. H.
Armour, A. L.
Atkinson, Miss M., M.A.
Baker, Mrs. T.
Barnard, Rt. Hon. Lord, D.C.L.
*Bedson, Professor P. P., M.A., D.Sc.
Belger, H.
Black, T. P., M.A., M.Sc., Ph.D.
*Bolam, R. A., M.D.
Brack, Rev. M., B.A., B.Sc.
Bradshaw, F., D.Sc., M.A.
*Brady, Professor G. S., M.D., LL.D., D.Sc., F.R.S.
Brennan, A., B.Sc.
Brown, J. W. H.
*Bullerwell, J. W., M.Sc.
*Cairns, Mrs. C. W., B.Sc., B.Litt.
Cairns, C. W., M.Sc.
*Campbell, William, D.Sc., Ph.D.
Carr, Miss A. M.
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Coates, R.
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Cousins, H. W., M.Sc.
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Dean, H., A.R.S.M.
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*Garrett, F. C., D.Sc.
Gee, Rev. H., M.A., D.D.
Gill, E. Leonard, M.Sc. (*Associate Member*).
Gilchrist, Professor D. A., M.Sc.
Godwin, Rev. G. H., M.A.
Glenny, Miss (*Associate Member*).
*Gravell, John.
Greig, R. B.
Gurney, Miss L. M., B.Sc.
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Hall, W.
Hatton, R. G.
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Holohan, M., B.Sc.
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Hutchens, H. J., M.R.C.S., D.S.O.
Hutchinson, Miss J., B.Sc.
Jaques, A., B.Sc.
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*Jevons, F. B., M.A., D.Litt.
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O'Connor, Miss E.
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*Percival, A. L., M.D.
Pettigrew, J., B.A., B.Sc.
*Philipson, Professor Sir G. H., M.A., M.D., D.C.L.
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*Redmayne, R. R., M.A.
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Rushton, G.
*Sampson, Professor R. A., M.A , D.Sc., F.R.S.
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Smith, Professor D. Nichol, M.A.
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Sodeau, W. H., D.Sc.
Stephenson, H.
*Stroud, Professor Henry, M A., D Sc.
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Thompson, P. R.
Thornton, Professor W. M., D.Sc., D.Eng.
Trobridge, F. G.
Van der Heyden, A. F , M.A
*Watson, F. B., M.A., M.Sc.
Welford, R., M.A.
Widdas, H., B.Sc.
Woodcock, A. J. A.
Woolacott, David, D.Sc.
Wright, Prof. Mark R., M.A.

UNIVERSITY OF DURHAM PHILOSOPHICAL SOCIETY.

Balance Sheet for Session 1905-1906.

Income.

	£ s. d.	£ s. d.
To Balance from 1904-5		12 16 11
,, 2 Subscriptions, 1903-4 ...	0 10 0	
,, 17 ,, 1904-5 ..	4 5 0	
,, 102 ,, 1905-6 ..	25 10 0	
,, 1 ,, 1906-1910 ..	1 0 0	
——		31 5 0
,, Donations to the Reserve Fund		11 14 0
,, Sale of Proceedings and Authors' Reprints		1 3 6
		£56 19 5

Expenditure.

	£ s. d.
By Expenses of Holding Meetings	5 2 3
,, Printing and Issuing of Notices ...	4 2 1
,, Printing Proceedings	11 10 8
,, Stationery, Bookbinding, etc.	3 6 10½
,, Assistant Treasurer's Commission	1 2 6
,, Reserve Fund	11 14 0
,, Balance in Treasurer's Hands ...	20 1 0½
	£56 19 5

Audited and found correct,

HENRY LOUIS.

November 30th, 1906.

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Date of issue.	Date of issue.	Date of issue.